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SOME ASPECTS
OF
FOOD TECHNOLOGY IN INDIA

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Editors
H. A. B. PARPIA
R. C. BHUTIANI
K. L. RADHAKRISHNAN
A. N. SANKARAN
B. V. SUBBARAYAPPA

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
MYSORE

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PREFATORY NOTE

Investigations in the field of Food Science and Technology, and the closely allied branch of Nutrition, have been in progress in India for well over 40 years. The earlier work was essentially fundamental and had to be carried out with the very limited facilities that were available in those days. Moreover, the study of food preservation and processing had only a limited appeal because in the earlier days, there was plenty of food in the country and, in fact, India was an important exporter of foodgrains and other agricultural products up to the late thirties. There was, and still is, considerable amount of prejudice against processed products, excepting in a few categories for which markets had already been established largely through foreign enterprise. The chief users of canned and other processed products were the European residents and some of the bigger hotels and restaurants and these obtained their requirements through imports from other countries. The main opportunity of fresh development in the line came during the Second World War when supplies from other countries were largely cut off and when there was increasing demand for various categories of products from the Armed Forces that were stationed in India and in some of the neighbouring countries. Several new industries were started all over India and most of them were successful, because the demands were then considerable and the standards were not very exacting. The Government, through the then Food Department, gave considerable amount of advice and assistance to the industry but the prosperity was, however, only short-lived. As soon as the War ended, the market for several categories of products practically disappeared and many of the industries had to be closed down. Those which lingered on could hardly make both the ends meet.

Fresh interest in the possibility of the subject developed after the partition of the country and the realisation that the country is no longer in a favourable position in regard to food. The disastrous Bengal Famine of 1943 came as a sudden and severe shock to the whole country and made the people realise that unless there is adequate margin of food in various forms, the anti-social clements, which are always present, can create conditions of artificial scarcity. The earlier emphasis was naturally on control and distribution and, subsequently, on larger agricultural production. It is only comparatively recently that there has been increasing amount of interest in the application of modern methods of preservation and processing, largely with the object of conserving the available food resources of different kinds and in the production, enrichment and utilisation of different subsidiary foods.

The largest and the most successful among the food industries of the country like sugar, confectionery, fermented products of different kinds, *vanaspati* (hydrogenated oil), milling of rice, flour and oil, biscuits and bakery products, breakfast foods, etc., follow the same pattern as in several of the other countries. Some of them are still growing at a fast rate because of the increasing consumer demand, while others are making slower progress and are working well below their established capacity. Much credit is due to the organisation, drive and publicity behind some of the efforts. Some of them would have made better progress but for certain inherent difficulties such as erratic prices of raw materials, changes in Government policies and so forth. There is also the continuous conflict in respect of idealogies and interests such as those relating to mechanised installations on the one hand and labour-intensive small scale and cottage industries on the other. In certain cases, as in the fruit and vegetable preservation industry, the potential markets—both internal and external—are very large, but the industries have still to contend against prejudices, lack of different facilities, difficulties arising from the low purchasing power of a large section of the consumers, competition from cheap, but sub-standard products and so forth. The Government is doing everything possible to exercise the necessary control, but the difficulties are still there. With such a background, the industrialists are naturally reluctant to invest money on the development of new lines, however useful they may be, unless there is at least a certain minimum assured off-take. Under the conditions now prevailing in India, the Government has to take the lead in facilitating new developments, whereas in most of the other advanced countries, the lead has come almost exclusively from private enterprise. It is hoped, however, that the present difficulties are only transitory and that the conditions will improve considerably during the next few years. In the new developments, private enterprise assisted by scientists and technologists on the one hand and with Government support on the other, will have to play a very big part.

The present publication does not, by any means, claim to be a comprehensive document dealing with all the aspects of the developments of food science and technology in India. The object of the publication is not so much to discuss the well known and well established lines as to draw attention to certain other lines that hold out possibilities for development, with particular reference to the food situation in the country. Even among the new lines, some which offer scope for the future and on which a great deal of work has been done, have not been included. These omissions are not deliberate, but due to lack of certain facilities, including that of time. Some subjects like those bearing on *vanaspati*, milk substitutes of vegetable origin, etc., have been extensively covered in detailed publications issued under other

auspices. The present publication is essentially a compilation of contributions by some of the members of the Central Food Technological Research Institute, Mysore, dealing with certain aspects of study, on which a large amount of work has been done in the Institute during recent years. Some of these subjects deal with certain familiar lines, while others endeavour to cover those which are not so well known. Coming from different authors, the individual contributions do naturally vary in respect of the mode of presentation, thoroughness of detail and so forth. Some are essentially of the nature of reviews while others deal in detail with individual projects. Some indicate possibilities in certain fields where only a limited progress has been made. With such varied methods of approach and presentation, there will naturally be several shortcomings and even errors and omissions. It is earnestly hoped that these defects and deficiencies will be over-looked and that the publication would be received with the necessary consideration by all our readers. The immediate object is to bring to the notice, especially of our colleagues from the countries of the region, the FAO and other International Organisations and also to our Governmental authorities, certain aspects of scientific and technological work which, if adequately developed, would be of both immediate and long-range value not only to India but also to other countries which are similarly placed. If this object is fulfilled, even to a moderate extent, the publication would have amply justified itself.

Central Food Technological
Research Institute, Mysore
26th July, 1959.

V. SUBRAHMANYAN

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SOME ASPECTS OF THE UTILIZATION OF FOOD RESEARCH IN INDIA

(WORK OF THE C.F.T.R.I.)

By H. A. B. Parpia and V. Subrahmanyan

(Central Food Technological Research Institute, Mysore)

Shortage of food has become a serious problem in India and the gravity of the situation is likely to reach alarming proportions unless some immediate action can be taken for controlling it. It is estimated that the population of the country is 397 million at present and according to the Ford Foundation Report*, it is likely to reach 480 million by 1966—an increase of population at the rate of approximately 2 per cent per year. In order to feed this additional population of more than 80 million by 1966, it will be necessary to raise the annual production by about 20 per cent in the course of 5-6 years. Our experience of the recent past shows that it is going to be extremely difficult to achieve this increase by improved agricultural methods alone. The alternative of population control is also not likely to solve this problem immediately. More than 85 per cent of our people live in villages and our literacy is barely 15 per cent. To teach birth control to the common man in such circumstances is going to be a difficult and long term task. It is generally observed that birth control is a natural concomitant of industrialization, urbanization and higher standard of living. The per-capita income in India is approximately Rs 350 per year as against Rs. 15,000 in the U.S.A. India is a multi-cultural country with 14 different cultures and traditions and an equally large number of sociological barriers to accepting changes in the mode of life.

As the situation exists today, the average Indian barely manages to get food providing from 1,600 to 1,900 calories and that being basically carbohydrate, is nutritionally deficient. As against the minimum requirement of 65 g. of protein, the average person usually manages to get only 30-35 g. per day. This semi-starvation can be considered genetically worse than complete starvation as all the physical weaknesses are passed on for generations to come.

One of the most essential requirements for a free society is that there be sufficient food. Democracy can never survive in the midst of hunger and starvation. The modern concept of hunger embraces everything from the latent deficiencies commonly called conditions of undernourishment and malnutrition to absolute starvation.

While a number of organisations in the country are working towards increasing the agricultural production and also controlling population, there is need for research work with a view to conserve the already available food supplies. For example, if the loss of available cereals could be prevented by improved methods of storage, there would hardly be any need for importing these foods to meet the shortage. At present, the loss of perishable foods such as fruits, vegetables, eggs and fish, is also very high due to inadequate methods of packaging, transport and marketing. If these protective foods could be carefully preserved so that they could be consumed in larger quantities, it would go a long way in improving the dietary balance. It is well-known that the average Indian diet is extremely deficient in these protective foods. In view of this, the efforts of technological research have to be diverted towards conservation of the available foods through processing and preservation, as well as development of cheap new products to substitute and supplement the cereal foods. An effort of this kind would go a long way in overcoming the food shortage both qualitatively and quantitatively.

The task of a Food Research Institute of this type would be much easier in any economically developed and advanced country as there would be no need to cover such a wide range of activities as has to be done in India. Here we are faced with food problems in every village and town. These have to be solved by developing acceptable products from easily available raw materials with high yields per acre or by utilising produce which is being wasted at present or is not being utilized to its full advantage. In a country with a low economic standard of living like India, the

* The Government of India, *The Ford Foundation Report on India's Food Crisis and Steps to meet it*, April 1959.

staple foods are cereals. Therefore, an attempt has to be made to substitute and supplement these foods at a cost which would be within the reach of a common man. The development of such substitute products, however, is not the complete answer to the solution of the problem nor is their production on a pilot plant scale adequate for the purpose. Successful results can be obtained only when manufacture of the new products is economically feasible and when the common man accepts them as a regular part of his daily diet.

Most of the other papers deal with the laboratory research aspects of the problem while this paper deals essentially with the technological application of the research as well as the socio-economic aspects of the problems. The cycle could be considered complete only when the problem which was picked up from the field had been solved in a laboratory, pilot plant and finally offered to the common man in the field again. Efforts of this type not only require practical scientists and technologists with adequate experience but also a group of technologists who are fully aware of the socio-economic conditions and can understand the problems of a common man so as to make the final solution acceptable to him. The Extension Service of the Central Food Technological Research Institute is essentially an activity which concentrates its maximum effort on the last mentioned problem of utilisation of scientific research through all possible means in our under-developed economy so that a positive contribution can be made towards the over-all development programme of the country.

The activities therefore have to be planned in a manner so as to cover: utilisation of new processes developed at the Institute; provision of adequate technical assistance to the food processing industry for improving its existing production; preparation of plans for the development of new units of various productive capacities; formulation and implementation of educational programmes to make newly developed substitute and supplementary foods acceptable to the people in rural and urban areas; and prevention of waste of food materials already available in the country.

INDUSTRIAL LIAISON

One of the initial hurdles which India had to overcome so that the research could be utilized, was the lack of suitably qualified and experienced staff which was aware of the needs of the country. Food technology is a new field in the world and in India several of the lines are hardly 10 years old. The industry also had not developed to an extent where provision could be made for training of the technical staff in actual production and quality control problems. Much of the industry in India has developed from 'turn-key' units—knowledge and machinery imported from abroad—ready to go into operation. Thus, there is not sufficient initiative on the part of the industry to develop large scale new processes. The size of the industry is also small and the finances available are not adequate to take any major risks. With this background in view, the industrial liaison and process development work at the C.F.T.R.I. was started, the first effort being to establish working confidence between the research team and industry. This has been achieved, not only through direct contacts but also through various governmental and other organisations on which the Institute and the Industry are both jointly represented.

Technical Advisory Service: Our food industry is comparatively young, as can be seen from the following production data:

Name of the Industry		*Production in 1958 (in tons)**
1. Biscuit	...	17701.65
2. Confectionery	...	13361.36
3. Flour milling	...	816865
4. Aerated water	...	895700 gross bottles
5. Liquid glucose	...	4410.62
6. Dextrose	...	1662.95
7. Chocolate	...	372.11
8. Cocoa-powder	...	68.98
9. Butter	...	1919
10. Meat products	...	341
11. Cashewnut	...	18743
12. Breakfast food	...	1508
13. Fruit preservation	...	...

* Ministry of Commerce and Industry, Government of India (figures supplied to the Development Council meeting held on 4th July 1959).

The size of the food industry in India can easily be compared with small scale or cottage

scale industry in technologically advanced countries. Therefore, our industry is today faced with not only a number of technological and financial difficulties but also the basic problem of obtaining quality raw materials. During the last three years, the number of technical enquiries which we received from the industry has been rising steadily. During 1956, these amounted to about 200, in 1957 they had more than doubled and in 1958, the number reached almost 1000. These enquiries relate mainly to the regular quality control problems of preservation and processing of various types of foods. This is significant indication of the industry's awareness of the technical assistance and research facilities available in the country and of its efforts to take advantage of them. On the other hand, the Food Research Institute is taking a more realistic approach to these problems as a result of close liaison with the industry.

Only a few of the problems referred to the Institute related to any new research. Most of them could be answered from the information already available through scientific publications and periodicals. The real emphasis was to adapt many of these techniques to small scale production that would suit the requirements of the Indian manufacturer. The fruit and vegetable processing industry has been the most active in this direction. The next in order come cold storage, fish processing, confectionery and bakery industries.

With the encouragement which is being given to the development of small scale industries in the country, it has become necessary for us to prepare a large number of plans for the development of small scale fruit and vegetable processing industries which could be started with an expenditure of Rs. 10,000 and Rs. 25,000 and also for medium size industry involving a capital of Rs. 250,000.

Most of this technical advice including the supply of comprehensive schemes involving details of equipment, total capital expenditure, building, etc., has been supplied free of charge. We have now begun to realize, however, that many enquiries which we receive are from persons casually interested who have just written because they know that we are supplying the information free. It may be extremely helpful, therefore, in time to come if we could levy nominal fees based on the information to be supplied. An activity of this nature involves concentrated industrial engineering work and can keep several senior members of the staff busy full time.

Process Development: As we win the confidence of industry through the liaison and technical assistance activities, it becomes possible for us to establish close contact with the industrial units and approach them with a number of new processes which have been developed at the Institute. In fact, a time has come when the Industry has begun to show interest in new processes even before they are completed and in a number of cases are willing to take them over at the bench pilot level. During the last 4 years, we have given the following processes and products to the Industry:

1. Grain Storage

In an underdeveloped country like India, grain being a cheaper commodity, is the main staple food. Compared to the recommended 14 oz. of grain per day, the average daily consumption in India is approximately 18 oz. per person, while other vital protective foods needed in larger quantities are used to a much smaller extent. In view of this situation, the maximum emphasis is being laid on increasing cereal production. The target for the Third Five-Year Plan is 110 million tons of food grains.

At present, however, the storage and preservation of the existing production of grains is a serious problem. Large quantities are destroyed by insects and rodents and it is estimated that 5-10 per cent of the annual production is actually lost thereby. Therefore, the protection of grains using methods which are effective under indigenous conditions of storage and transport had to be developed. The workers at the Institute were able to develop a technique of fumigation using ethylene dibromide, a low vapour pressure fumigant, which does not require airtight warehouses and works very successfully under tropical climatic conditions. Having once eliminated the infestation, the problem is to

prevent reinfestation. As most of the grain in our country is stored and transported in jute bags, a technique was developed to chemically impregnate the bags so as to make them insect-proof for a period of 8-10 months.

Both the above techniques have been successfully demonstrated and are now being used by three commercial firms to great advantage. This not only has led to the preservation of valuable grain but also has helped in developing a new industry. It has been possible to develop a number of other useful techniques such as the one which combines the processes of fumigation and impregnation making it feasible for utilization in warehouses where large quantities of grains are stored in jute bags.

The techniques have been simplified so as to make them applicable on a very small scale whereby it is possible to fumigate even one single bag of grain or a small home silo. In the near future, it is intended to introduce these processes at the regulated grain marketing centres where the jute bags can be treated before the grain is bagged. In time to come, it is hoped that personnel will be trained to handle these processes and their services made available to the marketing centres as well as in the community development blocks.

Further work is in progress to develop techniques for biological control using bacterial spores which could destroy the harmful insects in the field itself and also to develop certain inert material such as treated clay and activated charcoal to destroy the insects. As no toxic chemical is involved, these methods can be used with greater safety by non-technical people.

2. Substitute Foods

(*a*) *Tapioca Macaroni:* In order to increase the production of food, one of the most effective means is to plant certain tuber crops like tapioca which give 5-6 times higher yield per acre than cereal crops. The problem, however, is tnat a crop of this nature, although high in carbohydrate is very poor in protein content. This deficiency, however, can be overcome by adding an easily available, low cost protein material. For this purpose, edible quality low fat groundnut meal was prepared. The final product known as 'Tapioca Macaroni' was developed using 60 per cent tapioca flour, 25 per cent wheat semolina and 15 per cent groundnut flour and manufactured in a variety of acceptable shapes such as rice grains, tubes, shells, etc. As can be seen from the table below, the nutritive value of this product is almost twice as high as that of rice.

Chemical composition (per 100g.)

Constituents	Tapioca macaroni	Rice
Moisture ...	10.8	12.5
Protein (N×6·25) ...	11.3	6.6
Fat ...	1.8	0.5
Ash ...	1.9	0.6
Fibre ...	0.6	0.2
Carbohydrates (by difference) ...	73.6	79.6
Calcium (mg.) ...	53.5	0.10
Phosphorus (mg.) ...	144.6	0.12
Iron (mg.) ...	3.0	0.8
Thiamine (mg.) ...	0.21	0.11
Nicotinic acid (mg.) ...	3.6	0.2
Riboflavin (mg.) ...	0.07	0.02

Considering our level of socio-economic development and the rural concentration of people, our next problem was to make the product acceptable to the common man. This is dealt with in detail under the Rural Extension Service work. The Government of Kerala State with the help of the Central Government has already agreed to start a unit for manufacturing 20 tons of tapioca macaroni per day. This Institute has at present a pilot plant with a production capacity of one ton per day.

(*b*) *Mysore Flour:* A flour containing 75 per cent tapioca and 25 per cent groundnut meal was utilized to advantage during the famine period for combatting the food shortage. Experiments with this product have established the possibility of its use as a normal item of food.

(*c*) *Nutro Flour:* A hardy plant, tapioca tolerates adverse weather conditions and thrives on marginal lands which cannot be used economically for cereal crops. It will grow in almost any part of the country. By utilizing tapioca in place of some wheat in the diet, the overall supply of foodstuffs would be enhanced. With these factors in view, we have developed a flour

composition which could be acceptable all over the country, but especially in the northern parts of India where wheat is the staple item in the diet. This flour containing 75 per cent whole wheat flour (*atta*), 17 per cent tapioca flour and 8 per cent groundnut flour, compares well nutritionally with wheat flour and lends itself to the preparation of dishes for which wheat flour is normally used. In the near future, we intend to carry out a well-planned pilot extension project in the rural and urban areas of U.P. to develop consumer acceptance for this product. The details of this project are discussed under Rural Extension Service. Once accepted by the people, the flour can be prepared by local mills according to the standardized composition and made available for marketing.

3. Supplementary Foods

Indian Multi-Purpose Food: The average Indian's daily intake of 30-35 g. of protein falls far short of the desired 65 grams established as necessary for good health. We are making, therefore, every effort to find cheap sources of quality protein. Oilseed meals have proved promising for this purpose and a large amount of work has been done utilizing this material. The Indian multi-purpose food has been standardized at the Institute with the following composition: edible, low fat groundnut meal, free from grit, cuticle and germ—75 parts; roasted Bengal gram *dhal*—25 parts; added vitamins and minerals. Happily, the proteins of groundnut and Bengal gram are observed to be complementary and the combination improves the nutritional quality considerably. The use of 1-2 oz. of this product daily by an individual, along with his regular meals, largely meets the deficiencies, especially that of protein. M.P.F., as it is popularly known, is being manufactured at the Institute at the rate of 1500 lbs. per day and is being sent to different parts of the country. UNICEF has shown interest in this process and has recently come forward to help the Government of Madras to set up a unit with a capacity of 10 tons per day. Favourable consumer acceptance, as a result of our extension work, has evoked statewide interest in Bengal, Bihar, Orissa and U.P. Plans have been prepared for establishing small units in different parts of the country which would cost approximately Rs. 100,000 each and have a capacity of a ton per day. The various oilseed meals available in the country are of the order of approximately 8 million tons per year and obviously could go a long way in helping to overcome the protein deficiency in particular and the food shortage in general. Information relating to the extension work done in this direction is described separately in the following pages.

4. Rice Bran Oil

India is a rice producing country with an estimated by-product of rice bran of approximately 2 million tons. This bran contains between 15 and 20 per cent oil. India is deficient in its requirement of edible oils. Much effort should be made, therefore, to utilize this additional source of oil. The extraction process using petroleum solvents is well-known. The Institute not only has shown ways to make use of this method but also has developed an alternate process using industrial alcohol as the solvent because of the shortage of the desired quality of petroleum solvents in our country. The Council of Scientific and Industrial Research and the Ministry of Commerce and Industry have formed a joint committee to develop this process on a commercial scale and a prototype extraction unit is to be established in the near future.

5. Preservation and Processing of Perishable Foods

(*a*) *Cold Storage:* Fruits and vegetables are valuable protective foods and are widely available in this country. A number of these foods, produced in large quantities in various areas of the country, have to be transported to the urban centres for marketing. Due to improper harvesting methods, careless handling, improper grading, lack of pre-packaging and transport, it is estimated that nearly 30 per cent of these protective foods are destroyed. The losses to the grower are so great that he is discouraged to produce more and the cost of transportation so heavy that the consumer prices are prohibitive. Cold storage facilities, now available in very few

centres, could contribute significantly in prevention of deterioration and waste of precious foodstuffs. The Institute has provided some very useful technical data on the cold storage of various indigenous perishables, helpful to the industry for preventing losses and encouraging the increase of the cold storage capacity. But for the shortage of foreign exchange for the purchase of refrigeration equipment, this industry could be multiplied manyfold. Very little was known about the temperature, humidity and other storage conditions of tropical fruits until the work at the Institute had been completed and today a large number of technical enquiries are received from the industry and the information is being provided to them regularly.

(*b*) *Packaging:* Large quantities of perishable foods are damaged due to defective packaging techniques. A programme is under way to improve such items as the indigenous fruit baskets and to prevent damage during handling. If ventilated railway wagons could be made available, the damage in transit would also be reduced greatly. Recommendations in this matter already have been made to the Railway Board.

(*c*) *Fruit and Vegetable Processing and Preservation:* Processing of surplus crops for manufacturing various items such as juices, squashes, canned foods, etc., is being done on a fairly good scale as shown in the table below:

Production of fruit and vegetable products in India in 1957*

Sl. No.	Name of the product		Quantity in tons	Value in Rs. (thousands)
1	Synthetic syrups	...	558	1,385
2	Fruit beverages	...	2,493	5,366
3	Juices and pulps	...	1,017	2,111
4	Canned fruits	...	1,335	2,855
5	Canned vegetables	...	2,733	4,417
6	Jams, jellies and marmalades	...	885	2,221
7	Chutney	...	784	1,666
8	Preserves and crystallised fruits	...	1,918	2,280
9	Tomato products and sauces	...	454	992
10	Vinegar	...	504	529
11	Pickles	...	6,546	1,992
12	Aerated fruit beverages and others	...	6,147	5,822

* Directorate of Marketing and Inspection Ministry of Agriculture, Govt. of India.

The production of processed fruits and vegetables is on the rise. The import restrictions have helped the industry's development to a considerable extent, and the subsidy on tin plate and the expected export subsidy on the price of sugar will go a long way in encouraging the further development of this industry. As further encouragement, the Railway Board will soon provide special low freight rates for transport of processed foods to ports for export. Seasonal surplusses could thus be processed and made use of for internal consumption as well as for export.

Some of the new processes developed at the Institute, now being used by the industry, and others, in which the industry has recently begun to show interest, are as follows:

(*i*) *Fruit Juice Powders:* The process developed for the manufacture of powders from fruit juices and pulps has already been leased to a firm which will go into commercial production shortly.

(*ii*) *Fruited Cereals and Strained Baby Foods:* A process has been developed at the Institute wherein 60 per cent fruit pulp is mixed with wheat flour and sugar to manufacture very high quality breakfast cereals. It is expected that the firm which has taken the process will go into production in the near future. A number of other firms also have shown interest in this process as well as in the manufacture of dehydrated strained baby foods, the latter mentioned, an item being imported until very recently.

(*iii*) *Garlic Powder:* Another process, which has attracted industry's active interest, is the technique for manufacturing garlic powder for condiment purposes, as well as that for the manufacture of tablets containing active allycin to prevent gastric disorders.

(*iv*) *Cashew Apple Products:* For every cashewnut produced, there is large sized cashew apple wasted. It is estimated that the wastage of cashew apples in the country at present is 250,000 tons. Though this fruit is a rich source of vitamin C, it contains some astringent principles which need eliminating, in order to make it palatable. The Institute has developed a simple process for the manufacture of cashew apple candy, juice and other products which overcomes this difficulty.

A number of demonstrations have already been given showing possibilities for starting cottage and small scale manufacture of these products.

(*v*) *Storage of Cashew Kernels:* The storage of cashew kernels has presented a problem for quite some time, specially for small-scale producers. In order to overcome this difficulty, a process was developed for deep frying and salting of cashew-nuts using an improved technique which has made it possible to preserve them for a period of more than one year without the need for vacuum or inert gas packing. This process has been given to three firms who are using it to advantage.

(*vi*) *Fungicidal Wax for Coating of Fruits:* As cold storage facilities are so limited, a method for prolonging the life of fresh fruits at room temperature was developed. The use of a fungicidal wax for coating the fruit has helped in doubling the life of most of the fruits without refrigeration. This process has been tried on a semi-commercial scale with good success. The cost for waxing barely amounts to a couple of rupees per 82-pound maund.

6. Parboiling

Parboiling of rice has been practised in India for centuries. There has, however, been much difficulty in convincing a consumer used to raw rice to substitute parboiled rice in his diet, primarily because of the bad smell which the commercially parboiled rice develops. This smell was found to be due to the fermentation which takes place during the 3 day soaking period of the process. Investigations in improving the technique have shown the possibility of introducing steaming during the soaking period which cuts down that time to one day and eliminates the undesirable fermentation. This not only has helped to improve the quality tremendously but also has increased the turnover of the manufacturer so that several rice mills have now adopted the improved process. The parboiling of rice improves its nutritive value and is also helpful in preventing the breakage of the grains during milling. From the quantitative point of view, parboiling increases the yield because of the higher moisture content and the overall reduction of milling losses.

7. Infant and Convalescent Foods

(*a*) *Infant Food:* Imported milk-based baby foods have dominated the Indian market for a long time past. Investigations established that cow's milk was not only too expensive but also in very short supply to build up an indigenous industry in this country. Buffalo's milk, surplus only in certain milk pockets in the country, was considered unsuitable due to its high curd tension which causes digestive disorders in infants. If the fat content could be lowered and the curd tension reduced, however, the milk was otherwise very suitable. While the former was very easy to correct, the latter reduction required concentrated research effort. The result of this research has been the development of a low curd-tension infant food from buffalo's milk by the C.F.T.R.I. The process has been leased to Kaira District Co-operative Milk Producer's Union, Anand, who will manufacture the product on a large scale. Several other infant food manufacturers have seen the advantage of this process and are establishing large processing units in the country. Because of the high fat content of buffalo's milk, butter is a valuable by-product of the process.

(*b*) *Malted Milk Foods:* Recommended especially for invalids and convalescents, malted milk food beverage preparations have been imported in large quantities into the country until recently. An indigenous process, commercially feasible, was needed and has now been developed at the Institute and has been leased to a firm which is expected to go into large-scale production as soon as they can obtain all the necessary equipment.

(*c*) *Baker's Yeast:* Baker's yeast, in large demand all over the country, has been imported from abroad until now. The technique standardised at the Institute for manufacture of active baker's yeast has been leased to a private firm.

(*d*) *Composite Protein Food:* Answering a long felt need for a composite protein food for the use of invalids and convalescents, a solubilised casein food fortified with vitamins was developed. After completion, this process has been leased to a pharmaceutical firm which will market it within the next few months under their own brand.

(*e*) *Tonic Beverages:* Although until recently India had imported most of its tonic beverages, there was sufficient knowledge available to develop a product of this type based on indigenous constituents. A tonic wine prepared from easily available raw materials, including medicinal herbs, was standardized and the process sold to industry.

8. Soyabean Products

(*a*) *Hydrolysed Protein Products:* Hydrolysed protein products, some of vegetarian origin, others of non-vegetarian, have been imported into the country in quantity until recently. The development of an indigenous industry to provide a similar product was economically desirable. At the Institute a process to hydrolyse soyabean protein with the help of mould, producing a pasty product which could be utilised as sandwich spread or a soup preparation was developed for a private firm and is being marketed under their own brand.

(*b*) *Soya Sauce:* Soya sauce, containing 6-7 per cent protein could be a valuable supplement for the protein deficient Indian diet. A process using malt for hydrolysis of the protein was standardized and the industry has shown keen interest in utilizing it for large-scale manufacture.

9. Non-alcoholic Beverages

(*a*) *Passion Fruit Squash:* In a warm country like India, there is always a good market for different types of squashes and syrups for the preparation of cool fruit drinks. Passion fruit squash, utilizing a raw material which had heretofore been largely ignored, was standardized and the details released free of charge to the industry.

(*b*) *Ginger Cocktail:* Ginger, traditionally valued in India as a medicinal herb, was incorporated in a squash-like product also containing some fruit juices and other herbs. It has been standardized and given to the industry who are marketing it under their own brand.

(*c*) *Vegetable Milk Curd:* India is short of milk. As against the basic minimum requirement of 10 ounces *per capita,* an average person only gets 5 ounces. Therefore, the need has been felt to develop a cheap substitute which could be utilised in place of milk especially by the low income groups. The process for the vegetable milk from groundnuts was developed at the Institute and has been tried out successfully on a pilot scale. The product manufactured at the Institute is being sold regularly in Mysore City. A similar unit has been established at Sri Ramakrishna Vidyalaya, one of the recognised rural universities in Perianaickanpalayam, Coimbatore. The inmates of the hostel have been consuming 500 lbs. of the product everyday. There have been a number of requests from different parts of the country to help in establishing similar units. The curd manufactured from this milk costs 10 nP a pound as against 25 nP a pound of cow's milk curd. The nutritive value of the product compares fairly well with that of the cow's milk. There is need for extending the use of this product further.

RURAL EXTENSION SERVICE

The rural character of India is one basic fact we cannot ignore. Any scientific research or utilisation of it which fails to beneficially affect this more than 80 per cent of the country's population cannot be a worthwhile contribution towards the solution of the food problem. The task of the scientist and technologist cannot be accomplished without reference to the villager and his environment. Any new food product, must prove itself in such a way that it will not mean any drastic change in food habits. The traditions and superstitions of centuries cannot be altered overnight, even if such an alteration is scientifically beneficial. The low literacy and poor standard of living are factors that strengthen the hold of tradition and attempts to introduce changes are regarded with suspicion. A successful rural extension programme is the result of careful planning and shrewed selection of personnel. A skilful worker understands the villagers' background as he goes to the area, lives with the people for some time and wins their confidence before asking them to try the new product (or idea). A sociologically biased food scientist is a rare person but our success depends on finding sincere people and training them. Fortunately,

the community development programme has broken much new ground and our extension worker can learn much from the new and varied experience of the block workers. This gigantic 'grass roots' effort is unique and has already made dramatic changes in the countryside.

(*a*) *Tapioca Macaroni in Kerala:* With this situation understood, we launched a campaign to make the tapioca macaroni acceptable to the people. To begin with, it was essential to choose a particular area of the country where the raw materials for the manufacture of the product were available and where it would be possible to manufacture it on a large-scale eventually. Kerala seemed a logical starting place. The success of the programme depended on close co-ordination between government authorities especially those in charge of food and agriculture, community development work, industries, health and the tapioca board. A committee was formed representing all these agencies as well as members of the Institute. A comprehensive programme of extension work was outlined covering the various NES blocks all over the State. Demonstrations by our extension team in close collaboration with all cadres of community development workers, were given over a period of eleven months. At first, as we had expected there would be, there was tremendous social resistance to the product. When, however, it was acknowledged that the product could be cooked to suit the dietary habits and taste of the ordinary man and also that it was easy to cook, has almost twice the nutrition of rice, and did not cost more than the cheapest quality rice, the enthusiasm began to grow. At every demonstration, the indigenous, simple, rural cooking methods which are traditional in every household, were used and the people themselves encouraged to cook the product. After much work, the product began to sell at the rate of $\frac{3}{4}$ ton per day. Our extension team consisted of two staff members from Kerala State. Later a macaroni propaganda officer was appointed by the State who, gradually, took over the work from our staff and is now carrying it further with the help of his team. A detailed report has been published in a booklet called 'Tapioca Macaroni Goes to the People'.

(*b*) *Distress Relief Work:* During the period 1953-54, there was acute hardship and distress consequent on failure of rains over a considerable part of Rayalaseema, then part of Madras, but now forming portions of Andhra and Mysore States. At that time, the Government had set up a number of gruel centres to provide free food to people. The Institute placed before the Government a proposal to make use of Mysore Flour (a combination of tapioca and groundnut flours) as a cheap and nutritious composition for feeding the people. Substantial quantities of the product were prepared and supplied by the Institute. Similar supplies were also made to some areas in Mysore State. The use of the composition which soon proved popular showed the possibilities in the line and indicated how the people in such areas can also produce such products.

In 1957, some of the districts of Mysore State were similarly affected. At that time, one nearby village was adopted by the Rotary Club of Mysore City who provided for the purchase of Mysore Flour and handed over the entire extension work to the Institute staff. In addition to the flour preparations, vegetable milk curd was manufactured daily and supplied also. The villagers gathered every day at a central place and prepared the *muddhes* (balls) co-operatively; then these were distributed to members of the community present, along with portions of groundnut curd. Everywhere an attempt was made to encourage self help as much as possible, thus the villager tided over the most difficult part of the year.

(*c*) *Nutro Flour:* Discussions are at present going on with the Government of U.P. concerning a proposal to introduce Nutro Flour (see under substitute foods) on a pilot scale in three districts of the State to determine its acceptability. Uttar Pradesh, a wheat producing State, can also provide edible quality groundnut meal. Tapioca has not been grown in the area so for, but the State Government has selected 50 centres where plantings have been started. In the near future, it is hoped the State will be able to grow its own tapioca on marginal lands, and once the flour becomes acceptable to the people, it will be manufactured locally. For the present trials, the flour will be supplied by the Institute.

(*d*) *Prevention of Spoilage of Perishable Foods:* Most of the agricultural produce for marketing fresh or for processing is grown in the rural areas. As mentioned above, investigations of handling procedures, packaging methods and transportation are being carried on.

(*e*) *Rural Problems of Grain Storage:* Simple methods of cottage scale preservation of surplus perishables would be very useful if widely taught in rural areas. Only those techniques not requiring complicated equipment could be used first, and in certain areas where the surplus is very large, it might be advisable to start a co-operative storage and preservation centre, the products being marketed through co-operative societies.

Extension work to introduce the aforementioned grain storage methods needs to be started intensively throughout the country. With the availability of more technically qualified extension workers, this important project could be undertaken.

Recently, an Extension Advisory Committee has been set up at the Central Government level, consisting of members of the Community Development Ministry and the Council of Scientific and Industrial Research. One of its main functions is to select the processes from various National Laboratories which could be utilized at the rural level, these processes being recommended to the Development Commissioners of the States who would select schemes according to their requirements and would implement them through their District Industries and Agricultural Officers in the various Community Development Centres. The response to the recommendations made by the Committee to some of the States has been quite encouraging.

URBAN EXTENSION SERVICE

Urban areas due to the growth of modern industry are being peopled by workers from rural areas who are not aware of the problems of health and nutrition in the city. Although the family income is generally far higher, the new type of work and the crowded living conditions impose physical and psychological strains on the worker which can eventually impair his health. If, however, his diet can be balanced and quality foods be made available to him, many of the deleterious effects of the situation can be alleviated. Several large private firms have become conscious of this problem and are providing good quality subsidized food in their canteens. Reports have already begun to indicate that with such feeding, the absenteeism has gone down and there is more satisfaction among the workers. This, however, affects only the working members and the rest of the family continue to suffer from malnutrition. Also, the number of firms willing and able to subsidize such feeding programmes is small.

Realising the vastness of the problem, our first effort has been to introduce the Indian multi-purpose food in the industrial canteens. The acceptance has been good and repeat orders come regularly, but unless we can reach the home too, the problem remains largely untouched. This will require a concerted campaign in the selected areas with the help of management, trade unions, workers' committees and the health authorities.

Protein malnutrition is particularly high among school going children. Therefore, an organised effort is being made at present to introduce Indian multipurpose food in schools three selected districts of Madras State. With the help of UNICEF, the State Government plan to establish a unit manufacturing 10 tons of MPF per day and utilize the entire off-take in their school lunch programme. Already, convincing demonstrations of MPF's nutritive value and adaptability have been carried out in institutional feeding experiments at our Institute and in co-operation with the Madras municipal corporation.

In urban areas, the lower middle class families are, in certain respects, in the most difficult position. With the earning of one member, they have not only to maintain the nutritional level of the family but also to keep up with certain standards of living. If the housewife could learn to preserve many of the fruit and vegetable products during the season, she would make a significant contribution to her family's diet as well as its budget. One urban mobile demonstration unit for training the housewives in food processing and preservation has been fully staffed and through

clubs and social organisations, as well as in various schools and colleges, is trying to reach this section of the population. We hope many of these latter mentioned schools and colleges will initiate their own food preservation courses before long as a regular part of the curriculum.

Organisation of community canning centres to help housewives co-operatively process seasonal produce would be a very desirable step. Units of this type set up in U.P. by the Directorate of Fruit Utilization have shown very encouraging results. There is need for extending this activity to all States.

FUTURE EXPANSION OF EXTENSION SERVICE

All these projects are only the modest beginning in view of the vastness of the problem. Miraculous results are not expected as work of this nature requires slow protracted effort and extensive ground work. Our staff is small and our resources limited—decisive factors in our ability to produce results.

With the establishment of the already approved regional research stations in various parts of the country, we hope to multiply our effectiveness and at the same time acquaint ourselves more intimately with the specific problems of each area. Each of the ten stations must have at least one mobile extension service unit which could be kept fully occupied in the nearby rural as well as urban areas.

Unless there is a concerted effort by all concerned, and especially the technologists, the food production targets of the Third Plan cannot be met. Even an increase in production, without improved methods of storage, preservation and other measures would be less meaningful as the spoilage and destruction would remain proportionate.

PUBLICATIONS

Without adequate information facilities, the industrial liaison and the rural and urban extension services cannot be very effective. As our external activities increase, the work on publications, leaflets, posters and such must be intensified. It is *not* possible for the food science extension workers to be present on the spot for assisting any industry at all times of the year nor is it possible for the rural and urban extension service workers to be available all over the country. Once the programme has been organised and begun successfully, it is usually taken over by local people, particularly the national extension service block workers. Contact with these workers and our Institute is strengthened through the various publications. At present we publish these regular journals as well as various other items of topical use from time to time.

Food Science: This is a monthly technical journal which publishes only the technical information covering research, review, abstracts from Indian and foreign (both English and other languages) journals and publications. The main object of this publication is to provide scientific and technical information available in India as well as abroad to fellow scientists as well as to industrial technologists in the country. The publication is running in its eighth volume at present.

Ahara Vijnana: This bulletin is published quarterly in the Kannada language. The country has about 19 million Kannada speaking people. Through the Community Development organisations, the Adult Education Council and the Directorate of Public Instruction, Mysore State, this publication has a subscription list of about 2,000, each copy being seen by about 50 persons. On the basis of the material presented in this bulletin, we receive a number of enquiries from various centres, for information on food processing and preservation.

Khadya Vigyan: Hindi is the official language of the country and is spoken or understood by two-thirds of the country's population at present. In order to serve the urban and rural areas effectively, therefore, a Hindi publication was started. At present, *Khadya Vigyan* has a circulation of approximately 15,000 and reaches various community development centres, schools and colleges, Members of Parliament and a large number of individuals.

Miscellaneous Publications: Over the last few years, the Institute has published several pamphlets, books, brochures, food science circulars, project circulars and about 700 research papers.

OTHER IMPORTANT SERVICES

(*a*) *Statistical Service:* The role of Statistics in any experimental work needs hardly any emphasis. The Statistics Unit—an important wing of the Division of Food Information, Statistics and Extension Services—assists the various research workers in the different divisions in the proper planning of their experiments and later carries out statistical analysis of the data from the experiments. The members of the staff of this Unit conducted in 1952 a large scale random sample survey for estimating the *per capita* consumption of salt and other articles of food in Mysore City. They also collaborate with the other research workers in nutrition surveys, diet surveys, sureys on growth-rate, consumer acceptance surveys, institution feeding experiments etc. They also assist the various food industries in carrying out productivity studies and in effecting quality control measures in production.

(*b*) *Library Service:* The Institute has a fairly comprehensive library consisting of about 5,000 volumes of journals and about 4,500 books. The library is receiving periodicals. Through exchanges with libraries of the other C.S.I.R. sister laboratories, we are able to supplement our collection.

(*c*) *Foreign Languages Service:* A considerable amount of information on food science and allied subjects is published in foreign languages—German, French, Spanish, Italian, Russian, etc. The Institute provides translation facilities to all the research workers through the technical translation service and also supplements it, when necessary, with the help of INSDOC (Indian National Scientific Documentation Centre). These facilities are also extended on occasions to other sister laboratories and to industry.

(*d*) *Photo Art Service:* The Photo Art Service of the Division of Information, Statistics and Extension Services is a fully equipped unit which assists in the organisation of exhibitions, by preparing various photographs, charts, etc., and also helps in the publication work. A considerable amount of scientific and technical photographic work is also undertaken by this unit for the various Divisions of the Institute, including the use of such techniques as photomicrography and macrophotography.

SUMMARY

The Institute since its beginning nine years ago has developed a number of processes which are being utilised commercially. The development of tapioca macaroni, nutro flour, the Mysore flour, the Indian multipurpose food, grain storage techniques, improved method for parboiling of rice, infant foods from surplus buffalo milk in certain regions, are some of the most important processes which can make valuable contributions towards solving the food problem of this country. A concerted effort has been made to develop these processes and to make the products acceptable to the people in the rural and urban areas of the country. All aspects of food including production, distribution and consumption require technological assistance which the Institute is endeavouring to provide through its Extension Services and Development Programmes.

RICE SUBSTITUTES

By D. S. Bhatia and V. Subrahmanyan
(*Central Food Technological Research Institute, Mysore*)

Historical

The term '*substitutes*' though scientifically sound is not literally a very happy one because it gives the impression that the class of products represented by it is of the nature of imitations or emergency compositions and consequently likely to be inferior to the natural products. Both during the past century and also during the present one, there have been several controversies about the relative merits of natural products and the so called artificial products as developed on the basis of scientific and technological researches. Practically all these controversies have ended not only with the recognition for the value of the so called artificial products but also in a number of cases, their superiority through higher concentration or purity and less cost as compared with the natural products. In recent years, the consumers have been attracted to accept and use such products by giving them new and even fancy names and also by advertising campaigns drawing attention to the excellent qualities of such products. In most parts of the world there is no longer any prejudice against such products once their qualities are scientifically established beyond all possible doubt.

The average man or woman in any part of the world is highly conservative about food and it is common knowledge that there is generally a considerable amount of reluctance and even resistance to change from a milled to an unmilled product—let alone from one foodgrain to another. At the same time, there is no longer any major secret about the compositions of foodgrains, the amino acid make-up of the proteins or the associated minerals or vitamins. One of the simplest in this respect—subject of course to varietal differences—is rice which is being consumed as the staple food by more than half the population of the world and for which there is an ever-growing demand. At the same time, a remarkable feature which we have yet to unravel is the nature of the forces that keep the components together so that even a drastic operation like boiling in water does not disintegrate the product. The compactness, which is noticeable, especially in the case of some of the superior varieties, the water washability, the ease of storage and transport (especially after polishing) and ease of digestion of the cooked product, are some of the attributes which have a great appeal.

At the same time, the grain is essentially a starchy product and the protein, though of good quality is low in quantity (generally of the order of 6-7 per cent). It is, therefore, a fascinating concept to develop a similar and even a better composition out of other cheaper raw materials and to confer on the blend the shape, size and the other properties of rice.

Such an approach would facilitate not only the processing and enhancement of the low grade food materials, but also in meeting a specific requirement in several of the densely peopled countries in the world which are already experiencing considerable difficulties in keeping pace with the growing requirements of the population. There would also be the added advantage that the processed product can be suitably enriched and fortified so as to make them into a better article of food than what people are normally able to attain. The significance of this can be well appreciated that in some of the poor vegetarian diets of India, rice forms at least 80 per cent of the total quantity of food. Essential pre-requisite for the success of such a product would be (1) abundant availability of cheap raw materials, (2) ease and simplicity of processing technique and (3) attractive colour, pleasing taste and flavour and versatile uses of the product so that the consumers can use it in the very manner to which they are normally accustomed. Such conditions are not easy to fulfil, but experience of the past decade has shown that through persistent thinking and effort, many of the problems can be solved. We are perhaps still a long way from perfection, but the beginning which has already been made and the success which has already attended the effort would clearly indicate that the desired conditions

are being gradually attained. The subject is one which could deserve concentrated efforts on the part of scientists and technologists in different parts of the world. There is even a strong case for International collaboration with substantial resources that would lead not only to complete standardization of conditions, but also to large-scale production. There is scope for a gigantic industry to be built up in this field and it may not be too much to hope that the next decade may see some important developments in this field.

Substitute foods came into being in the early years of the 20th century but the second world war gave a tremendous impetus to the development of such foods. In fact, excellent substitutes were developed to meet the shortage of materials like milk, cream, butter, cereals, egg products, meat products, coffee, tea, cocoa, etc. The available literature on the subject was consolidated and reported from these laboratories[1]. In the post-war years the subject has assumed increasing importance in view of the acute shortage of both bulk and protective foods in certain over-populated countries of the world. In the present article, developments and future potentialities in the field of grain substitutes only have been discussed.

In India, the production of grains in the years immediately following world war II fell much short of the requirements and the country was faced with a serious problem of making up this deficit. It was in the year 1949 that the concept of grain substitutes was initiated at the Central Food Technological Research Institute, Mysore. The idea was soon translated into systematic investigations and a large volume of work which has since been done is summarised here.

Our attention was first drawn to the rice grain. As a bulk food, rice has certain unique properties which are not shared by other food grains. It has a neutral taste and flavour and can be consumed as a savoury or a sweet dish. It is easily cooked and digested. Having got accustomed to such a soft grain, the average rice eater finds it difficult to change over to any other food materials. Serious attempts have been made to popularise wheat among rice eaters but the results have not been very encouraging. Food habits do change, but the process is rather time-consuming. The possibilities of developing simple techniques by which wheat, jowar and maize could be rendered palatable and amenable to easy cooking for use as rice substitutes were explored[2] but the losses of food material involved in processing made the approach uneconomical and even after the treatment, these grains did not cook to the same degree of softness as in the case of natural rice grain. Certain other seeds such as bamboo seeds[3] and seeds of sweet sorghum have also been suggested as rice substitutes[4]. Attempts were made in other countries also to convert the whole grains of wheat, barley and maize into rice-like products. In fact products like 'Rycena', 'Barley' rice, 'Mock' rice, 'Potato' rice, 'Heinrich' rice and 'Nor-ice' had appeared on the market. Such rice substitutes require the appropriate starting materials which are not themselves available in plenty in our country.

We therefore reasoned that the most practical approach would be to develop composite grains from materials which are cheap and which can be produced abundantly in the country. The two principal components of cereal grains are starch and proteins and in our search for abundant sources of these, we decided to concentrate on tapioca as a source of starch and oil-seed meals as the source of proteins. Tapioca (*Manihot utilissima*) grows well on comparatively poor soils and the yield of tuber, on a dry weight basis is about 3-4 times as much per acre as in the form of cereal grains. Among the oil-seeds of the country, groundnut (*Arachis hypogea*) was selected because of its abundant availability at a reasonably low price and the ease in its processing.

Preparation of Raw Materials

The first step taken was to standardise methods for the preparation of tapioca and groundnut flours.

Tapioca flour: The raw tuber dug out of soil, is washed and the outer skin and the inner rind are removed by a special knife. This operation is generally done in India by manual labour. The peeled tuber is then cut into thin

slices known as chips. They are dried in the sun. Great care has to be exercised so as to avoid contamination of the material with dust. The drying should be quick in order to avoid fungal growth which introduces undesirable flavour. The dried chips are ground in a hammer mill to the desired degree of fineness. Tapioca flour is a clean product, white in colour and it somewhat resembles wheat *maida* in appearance.

Groundnut flour: The groundnut is decorticated and the shelled kernels are put in a shaker-separator to remove residual shell, foreign matter and damaged kernels. The cleaned kernels are given a light roast in an electric roaster; the heated kernels are cooled and the red or brown cuticle (testa) is removed by mechanical scrubbing in a blancher or by manual labour. During the decuticling operation, germ is also removed. The decuticled kernels are re-examined to sort out any residual defective pieces. The cleaned material is then pressed in an oil expeller to obtain a press cake having a residual oil content of 6-8 per cent. The cake is ground in a hammer mill to obtain flour of desired fineness. Groundnut flour is a clean material, light cream in colour and having a pleasant flavour.

Processing of Blends

Earlier attempts in these laboratories succeeded in making round grains from a blend of tapioca and groundnut flour[5,6]. The blends consisted of 85-90 parts of tapioca and 10-15 parts of groundnut flour. The grain having 7-11 per cent moisture was found to store well for 8-10 months under normal conditions[7]. The nutritive value of the 'synthetic grain' was intensively studied[8,9] with the following blends:

Synthetic grain A — 90 parts tapioca flour + 10 parts of groundnut flour
Synthetic grain B — 87.5 ,, ,, ,, + 12.5 ,,
Synthetic grain C — 85 ,, ,, ,, + 15 ,,
Synthetic grain D — 80 ,, ,, ,, + 80 ,,

The nutritive value of a poor vegetarian diet based on grain A was found to be of the same order as that of rice diet. The nutritive values of grains C and D were significantly higher than those of rice and jowar diets and were of the same order as those of wheat and ragi diets. Nitrogen balance experiments showed that at a 5 per cent level of intake, the biological value of synthetic grain D proteins was inferior to that of rice protein while at 10 per cent level, these values were nearly of the same order. The protein efficiency ratios of synthetic grain and wheat were nearly equal both at 7.5 and 10 per cent levels of protein intake.

Although the round grain received general consumer acceptance, it was felt that the product would have better possibilities if grain could be made in rice shape. Considerable amount of experimental work was done before it became possible to process blends based on root starches. Like other root starches and unlike cereal starches tapioca starch tends to cook to a translucent and sticky mass. It was found, however, that on treatment with 40-50 per cent by weight of boiling water, the starch in the blend becomes sufficiently gelatinized to give a dough of desired physical properties for extrusion. The dough was, however, weak when made from a blend of tapioca and groundnut flour but it was found that addition of wheat semolina or flour ('maida') was necessary to obtain a dough which could be extruded and cut into various shapes. Like the usual macaroni products, the extruded grain tended to disintegrate on being washed and rubbed in cold water prior to cooking. The cooked grain was too soft to the bite and was rather sticky; the loss of solids in cooking water (gruel) was also heavy. It was found that, on heating to a temperature of 110-120° C for even a few minutes, the starch of the blend changed in character and that the individuality of grain was fairly well preserved. Gruel loss was also reduced. Further improvement was effected by spraying a coat of calcium caseinate on the finished grain. A thin coat corresponding to 3-4 per cent by weight made the grain fairly resistant to water. The coating also improved the nutritive value of the grain. The comparative chemical composition of some of the rice substitutes is given below[10].

Pilot Plant Trials

With the background of data collected in these laboratories, factory trials were carried out in the

Comparative chemical composition (per cent) of some of the rice substitutes as compared with that of natural rice

	Natural Rice[1]	Rycena[2]	Mock Rice[3]	Pearled barley[2] (Barley Rice)	Japanese 'Synthetic Rice'[4]		Mysore (India) 'Synthetic Rice'
					A	B	
Moisture ...	13.0	8.2	14.0	10.08	14.0	14.0	9.5
Protein (N×6.25) ...	6.9	10.7	10.7	9.85	3.7	7.0	14.2
Fat ...	0.4	1.6	1.8	1.88	0.3	0.5	1.9
Carbohydrates ...	79.2*	69.3†	77.5	69.0†	81.1	77.4*	71.7
Fibre ...	—	—	—	—	0.3	0.4	0.7
Ash ...	0.05	1.22	—	1.35	0.6	0.7	2.0
Calcium (as Ca) ...	0.01	0.05	0.018	0.36	—	—	0.19
Phosphorus (as P) ...	0.11	0.24	0.114	0.20	—	—	0.15
Thiamine (mg) ...	0.06	0.19	—	0.02	—	—	0.22
Calorific value per 100 g ...	348	343	353	340	344	343	361

[1] Health Bulletin No. 23 (Govt. of India, 1951).

[2] From pamphlet issued by Rycena Food Products Pty., Ltd., Melbourne.

[3] Same as semolina (M.R.C. Report, Series No. 235, 1946), 'Chemical Composition of Foods' (H.M.S.O., London).

[4] Rice Journal, **57**, 20-22 (February 1954) (Synthetic rice A is made up of potato starch 50 per cent, wheat flour 40 per cent, rice flour 10 per cent; and Synthetic rice B of potato starch 20 per cent, wheat flour 70 per cent and rice flour 10 per cent).

* Calculated by difference. † As starch. — Indicates figures not available.

United Kingdom and in Switzerland. It was ascertained that a blend consisting of tapioca flour (60 parts), groundnut flour (15 parts) and wheat semolina (25 parts) could be extruded in a macaroni press to obtain products in various forms. Collaborative efforts of Central Food Technological Research Institute, Mysore, and Messrs. Buhler Brothers, Uzwil, Switzerland led to the fabrication of the first plant for tapioca macaroni which is now in operation at this Institute. (The name 'Synthetic Rice' which was used earlier was subsequently changed to 'Tapioca Macaroni'). Details of the equipment and the manufacturing process have already been reported elsewhere[11] but a brief description is presented here.

The pilot plant at Mysore has a capacity of one ton per day. The plant consists of:

1. Hammer mill (MSE-2) fitted with various auxiliaries.
2. Vertical conical mixer.
3. Extrusion press (ATA).
4. Pre-drier.
5. Main drying-cum-roasting equipment (TTHA).

Manufacturing Process

Formula of Mix: The raw materials are blended in the following proportion. Tapioca flour 60 parts, groundnut flour 15 parts and wheat semolina 25 parts.

Dry-mixing: The three ingredients are blended in the vertical mixer. The average moisture content of the dry mix is 10-11 per cent.

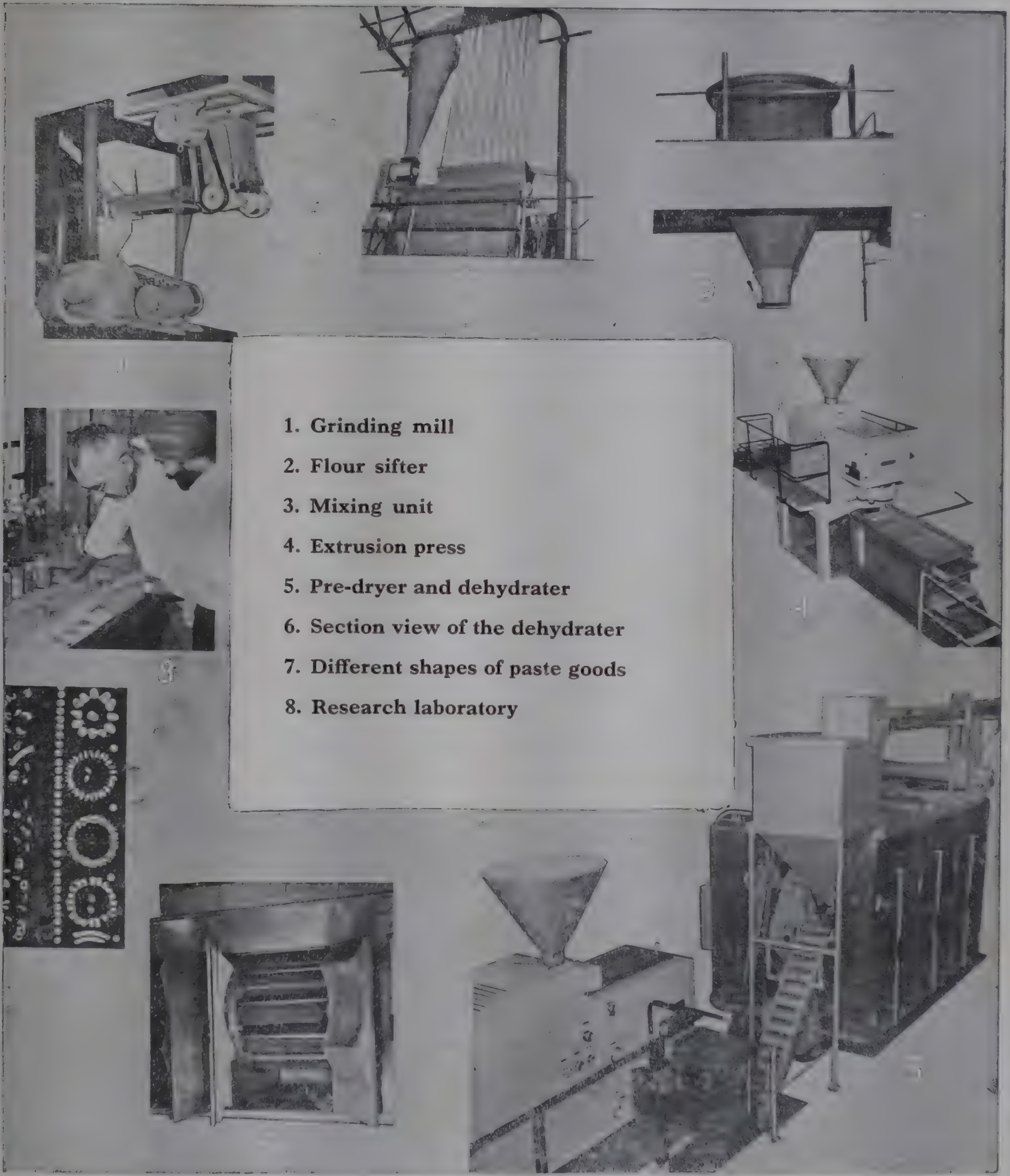
Dough Formation and Extrusion: The dough is formed by treating the blend with about 33 parts by weight of boiling water and kneading for a few minutes. The extruded product has a moisture content of about 33 per cent.

Pre-drying: The cut goods are passed through a predrier where the moisture is reduced to about 29.5 per cent.

Drying: The pre-dried material passes through a drier at temperatures between 50-60° C. The moisture content of the dried product is 10 per cent.

Heat-conditioning (roasting): The grain is subjected to a temperature of 115-120° C for a few minutes. The moisture content of the roasted material is about 5.8 per cent.

Modern Pilot Plant for Manufacturing Macaroni at the C.F.T.R.I.



1. Grinding mill
2. Flour sifter
3. Mixing unit
4. Extrusion press
5. Pre-dryer and dehydrater
6. Section view of the dehydrater
7. Different shapes of paste goods
8. Research laboratory

Packaging: The roasted product is cooled and stored in bulk for 24-48 hours during which period the product undergoes curing and equalization of moisture. The product is packed at about 7 per cent moisture content. It is packed in 1 lb. polythene bags which are heat-sealed.

Present Production at Mysore

Tapioca macaroni is being produced at present in three forms, namely, rice-shaped grains, short tubes and shells. To-date about 150 tons of the product have been produced in the pilot plant.

Cooking of the Product

Take 6 cups of water for every cup of macaroni. Bring the water to boil and drop macaroni gradually and stir. Allow the boiling to continue for 5-6 minutes and drain the gruel (cooking water) by pouring over a sieve. The macaroni is now ready for use for various dishes. The gruel may also be used after suitably spicing it. The macaroni should not be washed prior to cooking.

Nutritive Value of Tapioca Macaroni

The typical chemical composition of tapioca macaroni is as follows:

Moisture	...	10.8 per cent
Protein (N × 6.25)	...	11.3 ,,
Fat	...	1.8 ,,
Crude fibre	...	0.6 ,,
Ash	...	1.9 ,,
Carbohydrates (by diff.)	...	73.6 ,,
Calcium	...	53.6 mg. ,,
Phosphorus	...	144.6 ,, ,,
Iron	...	3.00 ,, ,,
Thiamine	...	0.21 ,, ,,
Nicotinic acid	...	3.6 ,, ,,
Riboflavin	...	0.07 ,, ,,

Institution feeding experiments with girls aged between 4 and 11 years for a period of 6 months have shown that the nutritional status of children fed on tapioca macaroni showed a slightly greater improvement as compared with those fed on rice diet[12]. Further studies[13] have shown that complete replacement of rice in a poor vegetarian diet by an equal quantity of tapioca macaroni brought about an apparently appreciable, but not significant, increase in the retention of N, Ca and P by children.

Extension Work for Popularization

A team of extension workers of this Institute carried out extensive demonstrations of the product and their efforts succeeded in making the product popular in the country. The details of the extension work have been embodied in Food Science Extension Service Bulletin No. 1 of the Institute[14]. Encouraged by the success of extension work and consumer acceptance of the product, the Government of Kerala have decided to set up a 20-ton plant with the financial assistance of the Central Government. This project is now under the active consideration of all concerned.

Scope for further Improvement

Though tapioca macaroni as produced now has found general acceptance among rice eaters, there is still scope for further improvement in the quality of the product. The grain as made now is rather soft to bite, is opaque and does not stand washing in cold water prior to cooking. It may be mentioned here that the average housewife in India washes the rice before cooking because the usual bazaar product may contain dust and dirt. Since tapioca macaroni is a clean product packed in plastic film bag, the necessity of washing should not really arise but it is felt that a certain section of people, particularly of orthodox type, may resort to washing of the grain before cooking.

The loss of solids during cooking into the cooking water is of the order of 12-13 per cent which is higher than that in the case of natural rice or wheat macaroni. Further work is in progress in these laboratories with a view to: (*i*) making the raw grain translucent and hard to bite, (*ii*) reducing the gruel loss to about 5-7 per cent and (*iii*) imparting water-washability to the grain.

The experiments so far conducted have indicated the possibilities of achieving these objectives by treatment of the materials with certain chemical agents. The heating of the dough before extrusion results in a grain which is hard and translucent and closely resembles the parboiled rice grain.

Future Outlook

The production of cereal grains in the country has shown a steady increase in the past decade and though it may be possible to meet the cereal requirement in the balanced diet of the people, we still suffer from an overall food shortage. This is due to the fact that 80-90 per cent of the calories of Indian dietary are met from cereals and tubers. Cereals are consumed in place of protective foods and thus the requirement for grains is inflated. Though serious efforts are being made by the country to increase the production of protective foods like milk, fish, meat, fruits and vegetables,

cereals and tubers will be called upon to meet most of the caloric requirement of our population in the immediate future. The present approach of making composite grains offers a part solution of the problem as it enables conversion of low-grade and high-yielding food materials into balanced cereal substitutes. Our aim in developing tapioca macaroni is not to replace the rice in the diet of the rice eater but to give him extra food which he can use without changing any of his food habits. Tapioca macaroni can find use in almost all preparations which are normally made out of rice.

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RICE TECHNOLOGY IN INDIA

By H. S. R. Desikachar and V. Subrahmanyan

(*Central Food Technological Research Institute, Mysore*)

The object of technology relating to any particular food is to promote the best and the most efficient utilisation of that food by suggesting improvements in current or traditional methods or to find new edible or industrial applications for it or its by-products. This is also true with respect to rice which is the staple food crop of India. The field of rice technology covers many aspects, the most important of which are: (*i*) milling and parboiling; (*ii*) composition and nutritive value and the effect of different cooking and other processing techniques on the nutritive value; (*iii*) by-products of the milling industry and their utilisation; (*iv*) culinary quality of rice as affected by variety and age after harvest; (*v*) breakfast foods and other ready-to-serve dishes from rice; (*vi*) storage problems and (*vii*) basic problems of research. As the scope of the subject is quite vast, only a brief summary of the work done on the subject is made in this review.

Milling and Parboiling

Parboiling and milling are two allied industries and although they are scattered throughout the country, they constitute the largest food industry in India. Nearly 50 per cent of the total production of rice is parboiled and the practice is becoming more and more popular because parboiling gives an extra 5-10 per cent yield of head rice and thus adds to the economy of rice milling. The increasing production of high-yielding soft varieties of paddy has also added to the importance of the parboiling industry because the soft varieties have necessarily to be hardened by the parboiling treatment before they can be milled.

Parboiling Methods and their Improvement

In spite of the large production of parboiled rice in the country, the quality of rice is generally unsatisfactory and production is governed by traditional methods. The customary methods involve the soaking of the paddy in water for two or three days. During this prolonged soaking period, fermentation sets in and the rice picks up an undesirable off-flavour. If inclement weather prevails during the drying of the paddy in the open, the fermented smell accentuates itself.

In order to make a scientific study of the traditional parboiling process, the Government of India set up a Rice Technology Committee under the Ministry of Food and this Committee did pioneering work in the field. The Committee suggested that instead of soaking the paddy in cold water for 2-3 days, the temperature of the soak water could be increased to 65-70°C whereby the soaking period is reduced to a few hours only and the fermented smell completely eliminated[1]. The applicability of this 'hot soaking' process to rice parboiling mills has been extensively studied at the Central Food Technological Research Institute, Mysore[2,3]. It has been shown that with minor changes in the customary methods, the principle of hot soaking can be applied and that this improved method can be more economical besides giving a wholesome product free from smell. A new parboiling tank for demonstrating the improved process on a commercial scale has recently been constructed in a rice mill near Mysore.

Sun-drying is the prevalent method for drying of the parboiled paddy all over India. Provided there is adequate sunshine, it gives a perfectly dry product. However, in seasons when the weather is cloudy or in places where there is rainy weather for a large part of the year, the drying of parboiled paddy cannot be done satisfactorily. To meet such situations, there is need for mechanical driers of such design as will make the process simple and cheap. Work on study of the performance of suitable types of driers for the drying of parboiled paddy is in progress at the Central Food Technological Research Institute, Mysore and at the Department of Applied Chemistry, Calcutta University.

Milling Methods and Machinery used

Before the advent of the mechanical mills, traditional methods grouped under the name of 'hand-pounding' were in vogue and these still continue to be used in the villages for milling of rice in small quantities. These methods are being replaced by mechanical mills all over India and in fact the mechanical mill has made inroads so fast that it has become necessary for the Government to encourage 'hand-pounding' in view of the employment potentialities which the latter offers to the rural population.

The mechanical mill has nearly made the hand-pounding industry outmoded because it is very quick, efficient and above all labour-saving. Two types of mills are generally employed. The small unit that comes under the commercial name 'huller' combines the dehusking and the polishing in one operation. The grains get very much heated during the milling and there is also high breakage in the rice. Hence the use of hullers is uneconomical. The official policy is to discontinue the grant of licences for the starting of new 'huller' units. If the use of hullers is diverted entirely to the milling of parboiled rice, the above disadvantage could be overcome because parboiled rice, being harder, can stand abrasion during the milling without suffering much breakage.

The larger automatic rice mills have a capacity ranging from ½-1 ton/hour and are mostly used in places where large quantity of raw rice is milled. As the dehusking and polishing are done separately and the polishing is done gradually and in stages in one or more polishing cones, the breakage of rice is reduced to the minimum and thus the yield of head rice is about 10 per cent higher than in the 'hullers'. Another advantage of these large units is that the degree of polishing of the rice can be controlled to any desired extent. Undermilled rice equal in nutritive value to that of hand-pounded rice can be easily produced.

Until about 20 years ago, the machinery for the milling used to be imported. The manufacture of machinery was slowly started by certain Indian firms and at present the equipment is entirely fabricated in India. Some Indian equipment is also exported. Research is, however, necessary with regard to effecting improvements in design

with a view to making the equipment more compact and efficient and improving the yield of head rice by reducing breakage during polishing to the minimum.

Nutritional Studies

As rice forms the staple food contributing to nearly three-fourths of the daily diet of the rice eater, the nutritive value of the rice is an important factor. Early studies on the nutritive value of rice were first initiated by McCarrison[4], Subrahmanyan *et al*[5] and Aykroyd *et al.*[6] The high nutritive value of the coarse and coloured varieties of rice was first pointed out by Sadasivan and Sreenivasan[7]. The higher vitamin B_1 content of parboiled rice was also demonstrated by them[6,7]. The considerable losses of vitamin B_1 and nicotinic acid in rice during washing and cooking were determined by Ranganathan *et al*[8] and Swaminathan[9] at Coonoor. The superiority of parboiled rice over raw rice with respect to its resistance against loss by washing prior to cooking was also demonstrated at Coonoor[10].

The composition and vitamin values of pure strains of rice have been more recently determined by Bannerjee and Guha[11] and Chitre *et al*[12]. Sampath and Seshu[13] have recently drawn attention to the higher protein content of certain varieties of rice. Although the protein content of normal varieties of rice after polishing is only 5-6 per cent, the biological value of the protein was found to be quite high both by growth and nitrogen balance studies[14, 15, 16, 17]. Amino acid analyses of the rice protein have also been carried out and all available data and literature on the subject have been reviewed by Kuppuswamy *et al*[18]. The effect of milling on overall nutritive value has recently been investigated[19] and the advantages of a medium polished rice pointed out by Kantha Joseph *et al*[20] and Rama Rao *et al*[21]. The possibility of simple methods for determining the degree of polishing in rice have been demonstrated by Desikachar[22].

From the nutritional point of view, the development of high-yielding varieties with high protein contents is an important problem. Another aspect which needs investigation is the development of varieties with high vitamin B_1 content so that even on polishing, sufficient amount of the vitamin is left in the rice. Alternatively if varieties where the vitamin is more evenly distributed instead of having a higher concentration on the periphery could be developed, the polishing will not remove much thiamine.

Utilisation of By-products of Rice Milling

The mechanisation of the milling process has made available large quantities of by-products, the utilisation and disposal of which is imperative and in fact could be made profitable. The chief by-products of the milling industry are hulls, bran and broken rice. The hulls are mostly being made use of as fuel for the boilers in the rice mills, the boiler ash being used along with farmyard manure. Other industrial uses of the hulls need to be developed in the country.

The other main by-product forming about 10 per cent of the rice milled is the bran containing the rice germ, the outer pericarp coating of the grain as well as varying amounts of the inner layers of rice scoured out during the polishing. The customary method of utilisation of the bran is as an animal feed. The value of rice bran as a source of edible oil (15-20 per cent) has recently been stressed and attempts are being made to set up a commercial-sized solvent extraction plant for recovery of the oil. The working data for a pilot plant scale unit have already been obtained by Raghunatha Rao and Krishnamurthy[23]. The fractionation of rice bran into a portion rich in oil, protein or fibre is an important problem for investigation and encouraging results have been obtained in a preliminary experiment.

Broken rice is another important by-product of the milling industry. It is obtained in many grades of purity and size. Most of the broken rice—especially the better grades—is now utilised for edible purposes i.e. for making into flour or semolina. Its commercial value is however lower than that of whole rice (also called head rice). The chief problem in utilising broken rice is the removal of stones and grit which are associated with it. Even with the best of care, it is rarely possible to remove the stones completely. A simple household device for separation of stones from broken rice employing the water

floatation principle, has recently been developed[24]. The usefulness of the 'paddy separators' forming part of the rice milling machinery for separation of stones from broken rice is being investigated and encouraging results have been obtained in initial studies.

Clean broken rice free from grits is a useful raw material for producing rice semolina needed for making traditional dishes like *Idli*, *Uppumav* etc. It might also be a starting material for 'reconstitution' into rice-shaped grains after suitable processing. The possibility of this has already been demonstrated at Mysore[25].

Cooking Methods and Differences in Cooking Quality due to Variety and Age after Harvest

The general method followed over most parts in India is to cook the rice to the required softness in water and throw off the excess cooking water (called the gruel or *Kanjee*). The cooked rice after draining the gruel is again slightly warmed over the fire so that the adhering water may either be absorbed by the rice or allowed to evaporate. The removal of the gruel prevents the stickiness in the cooked rice and gives a product with individual cooked grains standing apart. In this method of cooking rice in excess water and heating directly over fire, the grains are carried by the convection current of the boiling water, hit against each other, suffer breakage and for this reason gruel losses are high. If cooked in just the quantity of water as will be absorbed by the rice, there is danger of charring at the bottom of the vessel. Most middle class homes have therefore changed over to steam-cooking of rice to avoid the charring and to obtain a superior quality of cooked rice. The rice can be cooked in just as much water as the rice will absorb. Losses in the form of gruel are entirely avoided in this process.

The culinary quality of rice is judged by the consumer—apart from its whitish appearance—in terms of its ability to absorb water and swell to the maximum extent without becoming slushy but retaining the fluffiness. The rice should not cook to a sticky consistency. Differences in cooking quality arise due to two factors—variety and age of the rice. The fine hard-grained varieties are superior to the soft coarse-grained short duration varieties in cooking quality. This varietal difference in cooking quality is ascribed to the higher proportion of amylose contained in the hard-grained varieties[25].

Apart from this and irrespective of variety, the old stored rice is known to have a better culinary property than the new rice obtained from paddy fresh from harvest. The old rice swells more and also cooks to an integral consistency. The difference in cooking quality is explained on the basis of the higher amylase content of the new rice by Sreenivasan[26,27]. A change in the colloidal property of the rice has also been postulated by Rao[28]. The relative effects of the enzymatic and physical changes have recently been investigated[29,30]. A hardening of the cell walls has been noticed during storage and the expansion of individual grains has shown that old rice increases more in length and breadth than new rice grains[31].

A curing method based on steam treatment of the new paddy has been developed at the Central Food Technological Research Institute, Mysore, to give a product having the superior cooking properties of old rice[32]. The cured rice also has a higher vitamin content than the control old rice. This curing process has been used by the industry on a commercial scale. Further improvements to mechanise the process are being investigated.

Breakfast Foods and other Ready-to-serve Foods

Many processed foods from rice are popular and are being prepared and used all over the country. Such foods afford convenience in the usage and increase the taste appeal or digestibility of the product. One category of such foods consists of precooked or gelatinised rice which is dried or flaked so that it could be used straightaway either as such or along with milk or buttermilk. Flaked rice, popped rice, rice curls and *papads*, expanded rice, rice crispies etc., belong to this category. These are prepared either in the household or by small scale manufacturers by traditional methods. A scientific study of the processing methods is necessary in

order to simplify and improve the processes as also to improve the organoleptic quality and storage life of the product. The processing treatment involved in the preparation of such foods has been known to reduce the nutritive value[15].

Another category of such foods is the fermented dishes using rice as the base. Usually the rice either in the form of a flour or in the form of a coarse semolina is mixed with a pulse flour, preferably blackgram (*Phaseolus radiatus*) and allowed to ferment and then either steam cooked or cooked in shallow pans as cakes. The *Idli* and the *Dosai* are the most popular dishes of this kind used all over India. The former especially is a nutritious, leavened and easily digestible product. A study of the scientific aspects of the *Idli* fermentation has recently been carried out at the Central Food Technological Research Institute, Mysore, and a simplified household method of making *Idlis* has been developed[33, 34, 35]. A dry composite *Idli* flour which can be fermented and used for making *Idlis* has also been developed.

Storage Problems

The type of losses or spoilage during storage are by (1) rodent attack, (2) fungal and insect damage and (3) chemical deterioration due to oxidative or hydrolytic rancidity or other changes. The Directorate of Storage and Inspection of the Ministry of Food, Government of India is bestowing attention to popularise the use of standard types of storage structures both for bulk storage as well as storage of small amounts by the farmer. While insect attack is controlled by fumigation treatment, fungal damage is prevented by thorough drying of the paddy before storage.

The problem of bulk drying is a costly one. Even in places where there is adequate sunshine, the handling charges for sun-drying are considered uneconomical by the trader. Imperfect drying causes fungal damage, heat damage as well as colour changes. The 'yellow rice' of Japan which was shown to be toxic was a product damaged by fungal attack. The samples of 'yellow rice' examined in India were not found to be toxic although fungal attack was prominent[36]. The use of mechanical driers or other types of aerating equipment to reduce moisture in the paddy or at least to prevent accumulation of moisture pockets in paddy stored in bulk merits serious consideration. The Warehousing Corporation which has recently been formed is seized of this problem.

The problem of rancidity arises only when rice is stored in the milled condition. Unpolished rice or under-polished rice is more prone to deterioration in quality than fully polished rice. If the capacity of warehouses can be doubled, then paddy can be stored in the unhulled condition even for 2-3 years without deterioration. Otherwise, it is advisable to store the rice in the fully polished condition.

Basic Research on Rice and its Contribution to Technological Development

Applied or utilisation research is based on the data provided by fundamental research on the chemistry and synthesis of the constituents of raw materials, modification of properties by processing, mechanism of such chemical modifications etc. In the case of rice, basic researches on the chemical and physical changes during ripening, setting and storage of the grain, physiology of the rice plant, mechanism and type of starch synthesised in different varieties, quantity and amino acid composition of rice proteins, mechanism of change in properties during processing, vitamin content and their distribution in the grain are extremely important. Whatever advance has so far been made in the field of rice technology is due, in large measure, to the painstaking basic researches carried out by workers all over the world. Important contributions in this field have come from Indian work also. There is no doubt that these basic researches will continue to receive adequate attention so that they will contribute usefully to the advancement of rice technology.

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DETECTION AND ASSESSMENT OF INSECT INFESTATION IN STORED FOODSTUFFS

By S. Venkat Rao, S. K. Majumder and M. Swaminathan
(Central Food Technological Research Institute, Mysore)

Food grains get infested with insects either in fields before harvest or during post-harvest storage. The effects of insect infestations on the grains have been studied by various workers in India[1-8].

The kinds of damage brought about by various species of insects in grains and their products may be broadly classified under the following categories: *firstly*, there is direct loss of material as actually consumed by the insects and thereby lost to human use; *secondly*, there is the loss of food material by direct contamination with the excretory products, living and dead bodies and fragments of insects, and also by way of imparting disagreeable taste and odour to the food article and affecting the nutritional quality and *thirdly*, there is the loss of trade, goodwill and reputation of the grain dealer arising from the sale of infested food grains. In this review the second category of damage which is of prime consideration is discussed.

Changes effected in Foodstuffs by Insect Infestation

The type of infestation has a marked effect on the damage caused to grains and their products. The surface feeding moth larvae attack the embryo and thereby reduce the viability of seeds. Since

the germ and bran are the most nutritive portions of the grain, the pests also reduce the nutritive value of the grains[3, 6]. Studies have been carried out in India on the effects of insect infestations on stored grains with special reference to their nutritional qualities[1, 3, 4, 7, 8]. It is reported that the thiamine content of groundnut kernels is reduced by *Corcyra cephalonica* St. infestation, while *Tribolium castaneum* Hbst., *Oryzaephilus surinamensis* L. and *Necrobia rufipes* F. affect the quality and quantity of oil[1]. Kasargode and Deshpande have reported that insect damage to pods of groundnut results in lowering of the yield of oil[9]. Denaturation of protein and loss in thiamine contents have also been reported to be due to insect infestations in wheat and pulses[4, 5, 10]. Increase in free fat acidity[3, 5, 8] in stored grains has been attributed to insect activities during storage. Loaf volume[10] and the organoleptic qualities[13] of bread are affected adversely by insect infestation.

Another type of damage on foodstuffs is due to the habit of spinning silken webs by moths like the *Ephestia* sp. and *Plodia* sp.[6]. The loss of cereal products due to webbing is even more than the actual quantity eaten by these pests.

Apart from their direct effects on the quality of stored food products, insects indirectly bring about other undesirable changes. The metabolic activities of the insect population result in the development of heat and increase in moisture in grain bulk. These accelerate the microbial activities and consequent changes in foodstuffs.

Soysa and Jayawardena reported that the foodstuffs infested with mites and *Tribolium* sp. cause digestive disturbances and pulmonary disorders[14]. Certain species of mites and exuvae of *Trogoderma granaria* Everts cause dermatitis to labourers[6]. The insect fragments, cast skins, excreta and metabolic products like the odoriferous principles, may lead to some chronic effects in humans on continuous consumption of heavily infested products.

Need for Detecting Insect Infestation

Freeman[15] states that countries dependent on the import of a substantial part of their human and animal food and industrial raw materials, have hitherto tolerated excessive levels of infestation in such imports. Importers, processors and consumers are exhibiting increased resistance to accepting infested commodities throughout the world[16, 15].

The grain inspection procedures vary widely from country to country. In the United States damaged kernels and insect body parts in cereals and their products constitute the indices for unhygienic conditions[17]. In the United Kingdom at least the visual inspection is being increasingly adopted for judging the status of infestation in foodstuffs[18]. In India, the number of damaged kernels in the sample forms the index for assessing the extent of infestation as suggested by Sontakay[19] and others[20, 21]. The commercial samples of milled products present difficulty in assessing the extent of infestation. Moreover, the internal infestation or hidden infestation in kernels requires detailed consideration for its potential hazards to the quality of the grain. This aspect has received attention of many progressive millers in U.S.A. and they consider that grain with more than 0.5 per cent of insect-infested kernels is unfit for milling[22].

Emphasis on the sanitary status of cereal products in the U.S.A.[22], U.K.[18], Egypt[23], India[24], Canada[25], Australia[26] and many other oriental and occidental countries in terms of infestation free food grains and their products have prompted investigations on the various aspects of detection and estimation of insect contamination and filth. Recent researches on the aspect of detecting the incipient infestation in grains have led to the development of some techniques for inspecting commercial samples.

Detection of Internal Infestation

Some of the major stored grain pests as the *Sitophilus oryza* L. and *S. granarius* L., *oviposit* in the grain while *Rhizopertha dominica* F. and *Sitotroga cerealella* Oliv. burrow and feed within the kernels after the eggs are hatched. Further insect generation grows through various intermediate stages to maturity within the kernel, feeding on the endosperm. This kind of infestation causes serious damage to grain, which fact has been documented by White[27]. These apparently sound grains when exported become the sources of infestation during voyage.

Early methods proposed for the detection of internally infested kernels in commercial samples included visualization of egg plugs by acid fuchsin method of Frankenfeld[28], gentian violet method of Goossens[29] and berberine sulphate method of Milner[30]. These procedures fail to indicate the stage of insect development within the kernel. Nicholson *et al*[31] have suggested the counting of exit holes in insect infested grains and certain mechanical adjuncts have been recommended by Milner *et al*[32] to speed up this subjective test.

Methods have been developed for segregating the infested kernels from sound grains by air blast as well as floatation in liquids of varying density[17,32,33]. These methods await critical examinations for their applications in grain inspection.

Evaluation of living infestation in grain by electronic aural techniques of Adams *et al*[34] and carbon dioxide evolution and measurement method of Howe and Oxley[35] are in current use in the U.S.A. and U.K. respectively. Radiographical method for assessing internal infestation in grain is the most objective procedure at the present time. Harris[36] of the Food and Drug Administration of the U.S.A. reviewed the findings of his team with reference to the application of the various methods for inspecting grain for internal infestation and concluded that X-ray radiography adequately fulfils the requirements for a rapid, sensitive and simple technique. The grain radiography is being employed by F.D.A. for regulatory inspection of commercial sample for insect infestation. With the introduction of recent refinement in the use of photographic media, the wet processing of films has been eliminated[49] and thereby the X-ray technique has been improved.

Assessment of Total Infestation

The X-ray technique may not find immediate application in all the grain, dry fruit and spices exporting countries because of the initial cost involved. The grain processing industry in India and far eastern countries require objective tests for assessing not only the internal infestation but also external infestation. The test should, in general, indicate the total insect activity on the grain and their products. The real sanitary status of a grain or a flour sample will be better indicated by the assessment of total insect filth. The filth should include dead and living bodies of insects, their excreta and their body parts. This objective test is necessitated by the practice of adopting the disinfestation treatments and also milling when visual damage by the pests has started in the food grain stock. In a milled product, the index for detection and assessment of insect contamination should be indicative of total insect activities prior to sampling, as visual tests do not give correct sanitary status of the product.

In view of the above, the fragment count method of Harris *et al*[38] and the A.O.A.C. method[39] for detecting insect excreta in milled products are extremely useful. Although these procedures supply information on relative sanitary qualities, they cannot be applied for quantitative assessments.

The most logical quantitative approach for detecting and assessing insect contamination in foods lies in the detection and estimation of insect excreta or a metabolite associated with insect activity. In this line, the estimations of chitinous material[17] and uric acid[40,11,41-43] seem to be very promising. Potter and Shellenberger[37] have proposed a method for detecting insect material based on the spectrophotometric analysis of a hydroxyphenol occurring in the insect cuticle. Considerable work is still necessary before the method can be applied for regulatory inspection of grain and their products.

A promising line of investigation for determining the true index of total insect filth has emerged out of the results obtained by Subrahmanyan *et al*[44] on the production of uric acid in grains by insects. Experiments on the relation between the uric acid production on cereals[44,10,8] and pulses[45,7,12] by various species of insects under controlled conditions have yielded interesting results. A summary of the results is presented in Table I. Considerable amount of work has been carried out at the Central Food Technological Research Institute in India on the standardization of a method for estimating uric acid[44,46,12]. The earlier investigations dealt with the application of the method of Benedict and Franke for estimating uric acid in foodstuffs[47]. Further

TABLE I. *Uric acid and kernel damage in infested wheat, jowar, field bean and black gram*

Name of foodstuff	Kernel damage %	Uric acid mg/100 g.	Reference
Wheat (*Triticum vulgare*)	20.0	23.3	Subrahmanyan *et al Bull. cent. Food technol Res. Inst.* 1955, **4**, 86.
,,	80.2	79.5	
,,	78.8	98.6	
Jowar (*Sorghum vulgare*)	12.8	10.6	S. Venkat Rao *et al, J. Sci. Fd. Agric.* 1958, **9**, 837.
,,	36.0	61.7	,,
,,	61.3	73.0	,,
Field bean (*Dolihos lablab*)	6.1	103.0	S. Venkat Rao *et al, Food Sci* (in press)
,,	62.0	1912	
,,	94.0	5117	
Black gram (*Phaseolus mungo*)	6.7	389	,,
,,	15.2	664	,,
,,	45.4	2790	,,

refinement in the estimation method for uric acid has been introduced by Venkat Rao *et al*[48]. The survey carried out on some market samples of wheat and wheat flour revealed that uric acid can serve as a reliable index of the degree of insect infestation[13]. Relation of the organoleptic qualities with the uric acid contents of the market samples is given in Tables II and III.

The results obtained by workers of this Institute on the subject of assessment of the degree of insect infestation in foodstuffs, indicate the prospect of the application of the uric acid method for inspection and regulatory purposes. Although the physical method as the X-ray, may be applied with advantage, the initial cost involved for a suitable grain X-ray unit will prompt the use of chemical methods for routine grain grading in many countries. As the tropical agricultural countries export many of their produce, the development of a suitable chemical technique will find wide application for assessing the sanitary status of their export to decide on the application of disinfestation treatments prior to shipment.

TABLE II. *Uric acid content, kernel damage and organoleptic acceptability in market samples of soft wheat*

Uric acid range (mg/100 g.)	Size of samples[1] %	Kernel damage %			Organoleptic score [2]	
		Minimum	Maximum	Average	Dough	Chapati (unleavened bread)
0-1	36.5	0	3.5	0.4	7.0	7.0
1.1-5	41.2	0	10.4	5.6	6.5	6.5
5.1-10	18.8	2.7	10.8	7.3	6.5	6.5
10.1-15	3.5	9.4	18.5	14.8	4.0	4.0

[1] Total number of samples analysed=85

[2] Samples with organoleptic score higher than 4 are acceptable.

TABLE III. *Uric acid content and organoleptic acceptability in market samples of whole wheat flour*

Uric acid range (mg/100 g.)	Size of (samples[1]) %	Organoleptic score[2]	
		Dough	Chapati (unleavened bread)
0-5	45	6.5	6.5
5.1-15	28.3	4	5
15.1-30	3.3	3	4
30.1-158	23.4	2	3.5

[1] Total number of samples analysed=60

[2] Samples with organoleptic score higher than 4 are acceptable.

Need for a legal standard for food grains and their products has been felt by many countries for home use and for export. The public laws in some countries although prescribe a tolerance limit for insect contamination in food, the toxicological and pharmacological basis of the levels still require experimental verification. International co-operation in such studies to establish the tolerances and educating the commercial community on the adoption of sanitary measures will aid to minimise the hazards of insect infestation in grains to the consumers and limit the spread of pests from country to country.

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UTILIZATION OF TUBER CROPS FOR MEETING FOOD SHORTAGE

By V. Subrahmanyan and M. Swaminathan

(*Central Food Technological Research Institute, Mysore*)

Roots and tubers have been used along with cereals as staple foods by mankind from very early times[1]. They are next in importance to cereals, as sources of energy in the diets of people in several countries[2]. One of the most important food problems of India and many other densely populated countries in Asia and Far East is the provision of adequate quantities of cereals in the diet to meet the calorie requirements of the people. The total production of food grains has no doubt been steadily increasing as a result of employing improved methods of irrigation and agriculture but at the same time the demand from the growing population has also been increasing. As a result of this, the *per capita* national cereal supplies in India has remained more or less constant. Consequently India has to import continuously food grains for making up the shortage. In view of the high cost involved in importing food grains, it has become increasingly necessary to make up the cereal deficit by the use of other foods. Among these, the most promising are the roots and tubers such as tapioca, sweet potato and potato, which yield two or three times as much calories per acre as cereals.

Consumption of Cereals and Roots and Tuber Crops in different Countries

Data regarding the *per capita* daily consumption of cereals and roots and tubers in certain countries of the world are given in Table I.

TABLE I. *Net consumption of cereals and roots and tubers in different countries** (*per day per person*)

Country	Period	Cereals (oz)	Potatoes and other starchy roots (oz)	Calories
Europe				
France ...	1956–57	10.0	13.0	2980
West Germany ...	1956–57	9.0	15.0	2990
Ireland ...	1954–56	13.0	18.2	3590
United Kingdom	1956–57	8.7	9.5	3120
North America				
U.S.A. ...	1956–57	6.8	4.7	3150
Canada ...	1956–57	7.2	7.4	3160
Oceania				
Australia ...	1954–55	9.1	4.7	3160
New Zealand ...	1954–56	8.6	5.1	3380
Latin America				
Argentina ...	1955	10.2	7.6	2970
Brazil ...	1951–52	9.1	11.8	2350
Asia				
Phillipines ...	1954–55	13.0	5.0	
Japan ...	1955	15.0	6.7	2050
India ...	1954–55	12.9	1.2	1880

* Year book of Food and Agriculture (1957), F. A. O., Rome.

It is evident that the *per capita* daily consumption of cereals in different countries ranges from 6.8 ounces in U.S.A. to 15 ounces in Japan as compared with 12 ounces in India. The *per capita* daily consumption of roots and tubers which include mainly potato, sweet potato and tapioca (in certain countries only) ranges from 1.2 ounces in India to 18.2 ounces in Ireland[2]. Among the roots and tubers, potato is consumed in large quantities in Europe and North America, sweet potato in Japan and tapioca in certain Latin American and Asian countries.

It is interesting to note that potato supplies about 20-30 per cent of the calories in the diet of the people in France, West Germany and Ireland. The Irish National Nutrition Survey has revealed *that the average per capita consumption of potato in Ireland ranges from 12 to 30 ounces per day*[4]. The above data show that roots and tubers are being consumed in substantially large quantities in several Asian and European countries for making up the shortage in the supply of cereals. Since the present supply of food grains in India is inadequate to meet the calorie requirements of the population, increased production and consumption of roots and tubers will help to overcome the cereal shortage.

Relative Yield of Calories per Acre from certain Cereals and Roots and Tubers in India

Data regarding the average yield of calories from certain cereals and roots and tubers in India are shown in Table II.

TABLE II. *Yield of calories from roots and tubers as compared with cereals in India*

Commodity	Average yield per acre (lbs) 1956–57	Calories per acre
Rice ...	799	1,278,400
Wheat ...	621	993,600
Jowar ...	402	643,200
Ragi ...	659	1,054,400
Potato ...	4342	1,954,216
Sweet potato ...	9748	3,994,816
Tapioca ...	6467	4,656,240

The data presented in the table show that potato yields about *twice* as much calories, and sweet potato and tapioca yield about *thrice* as much calories as common cereals. It is therefore obvious that by increasing the production and consumption of roots and tubers, it is possible to make up the shortage in the supply of cereals in the country.

Nutritive Value of Roots and Tubers

The chemical composition of potato, sweet potato and tapioca is given in Table III.

It is obvious from the data presented in the table that sweet potato and tapioca are deficient in proteins as compared with rice. Potato on the other hand is definitely superior in this respect, the nitrogen content on dry basis, being of the same order as that of certain cereals. In view of their low protein content, tapioca and sweet potato can be used only as *partial* substitutes for cereals. At the same time, it will be desirable to supplement the diet with foods rich in proteins. The most promising among the protein rich foods available in India, are pulses and oilseed meals. While the former is consumed as a regular item in the daily diet, the latter have not so far been used as supplements to human diets. Among the oilseed meals, groundnut meal is available in large quantities and can be used as a supplement to average diets.

Utilisation of Roots and Tubers and Blends of Tapioca Flour and Low-fat Groundnut Flour in Common Food Preparations

Among the roots and tubers, potato and sweet potato are quite popular all over India as a vegetable. There is a strong case for increasing their production and making them available to the people all round the year. At present tapioca is grown for food only in the Kerala State. The crop is grown to a smaller extent in Madras for the manufacture of sago. Tapioca possesses the following advantages over potato and sweet potato: (*i*) It is very much cheaper than sweet potato or potato, (*ii*) It can readily be dried in the sun, and the dried chips preserved over long periods and (*iii*) The dried tapioca chips yield on powdering an attractive white flour which can be blended with cereal and groundnut flours and used in the dietary. The chemical composition of blends of tapioca, groundnut and cereal flours are given in Table III.

Investigations carried out at the Central Food Technological Research Institute, Mysore have shown that *chappatis* and *pooris* prepared from a blend of wheat flour (70 parts), tapioca flour (25 parts) and low-fat groundnut flour (5 parts) are equally acceptable as those prepared from wheat flour[5]. Further, a blend of tapioca flour (75 parts) and low-fat groundnut flour (25 parts) could be admixed to the extent of 25 per cent with other cereal and millet flours in many common food preparations. Thus with increase in the production and consumption of tapioca and groundnut flours a substantial saving in the cereal consumption can be effected. This will also eliminate the necessity for importing food grains from other countries.

Investigations on the Value of Roots and Tubers as partial Substitutes for Cereals

In view of the importance of roots and tubers in the food economy of India and other densely populated countries, investigations were carried out at the Central Food Technological Research Institute, Mysore during the last few years to study the effect of partial replacement of cereals with roots and tubers on the nutritive value of the diets[6-10]. These investigations may be broadly classified under the following heads: (1) growth experiments on animals (2) metabolism studies in adults and (3) growth experiments on children. A brief account of the results obtained is given below:

Animal experiments: The effect of replacing 25 per cent of rice, wheat and *ragi* in poor Indian

TABLE III. *Chemical composition of roots and tubers, cereals, tapioca flour and low fat groundnut flour and their blends*
(Values per 100g)

Sl. No.	Name of food	Protein ($N \times 6.25$) (g)	Fat (g)	Carbo-hydrate (by diff) (g)	Calorific value	Calcium (g)	Phosphorus (g)	Iron (mg)	Thiamine (mg)	Riboflavin (mg)	Nicotinic acid (mg)
1	Potato, fresh ...	1.6	0.1	22.9	99	0.01	0.03	0.7	0.01	0.01	1.2
2	Sweet potato, fresh ...	1.2	0.3	31.0	132	0.02	0.05	0.8	0.08	0.04	0.7
3	Tapioca, fresh ...	0.7	0.2	38.7	159	0.03	0.04	0.9	0.04	0.02	0.5
4	Low fat groundnut flour ...	49.8	8.9	20.8	374	0.07	0.50	6.0	0.95	0.20	19.5
5	Tapioca flour ...	1.7	0.3	83.1	353	0.06	0.08	4.4	0.12	0.11	1.8
6	Mysore flour—tapioca flour (75 parts) and groundnut flour (25 parts) ...	13.8	2.7	69.8	363	0.66	0.18	3.6	0.31	0.07	5.4
7	Whole wheat flour ...	12.1	1.7	72.2	353	0.04	0.32	7.3	0.54	0.12	5.0
8	Whole wheat flour (75 parts) + tapioca flour (25 parts) ...	9.4	1.3	74.9	353	0.05	0.26	6.5	0.44	0.10	4.3
9	Whole wheat flour (75 parts) + tapioca (20 parts) + groundnut flour (5 parts) ...	11.8	1.7	72.8	354	0.05	0.28	6.6	0.48	0.10	5.2
10	Jowar flour ...	10.4	1.9	74.0	355	0.03	0.28	6.2	0.35	0.09	1.8
11	Jowar flour (75 parts) + tapioca flour (25 parts) ...	8.2	1.5	75.8	356	0.04	0.23	5.8	0.29	0.08	1.9
12	Jowar flour (75 parts) + tapioca flour (20 parts) + groundnut flour (5 parts) ...	10.6	1.9	73.7	357	0.04	0.25	6.9	0.33	0.08	2.8
13	Ragi flour ...	7.1	1.3	76.3	345	0.33	0.27	5.4	0.42	0.10	1.1
14	Ragi flour (75 parts) + tapioca flour (25 parts)	5.7	1.1	78.1	347	0.26	0.22	5.2	0.36	0.09	2.3
15	Ragi flour (75 parts) + tapioca flour (20 parts) + groundnut flour (5 parts) ...	8.2	1.5	76.0	348	0.26	0.25	5.3	0.39	0.09	2.3
16	Rice, raw milled ...	6·7	0.3	80.2	351	0.01	0.13	2.0	0.12	0.04	1.1
17	Rice, raw milled (75 parts) + tapioca flour (25 parts) ...	5.4	0.3	81.0	352	0.03	0.12	2.6	0.12	0.04	1.4
18	Rice, raw milled (75 parts) + tapioca flour (20 parts) + groundnut flour (5 parts) ...	7.8	0.7	78.9	353	0.02	0.14	2.7	0.16	0.04	2.3

diets by tapioca flour or a blend of tapioca flour (75 parts) and low-fat groundnut flour (25 parts) on the growth of albino rats was first studied[6]. The results are given in Table IV.

The results indicate that (1) substitution of rice, wheat, or ragi by tapioca flour to the extent of 25 per cent in poor vegetarian diets does not lead to any deterioration in the overall growth-promoting value of the diet in albino rats (2) substitution of the above grains by a blend of tapioca flour (75 parts) and groundnut flour (25 parts) to the extent of 25 parts in poor vegetarian diets, brought about a significant improvement in the nutritive value of the diets as judged by the growth of rats.

Metabolism studies on adult human beings: The effect of replacing 25 per cent of rice in the diet by tapioca flour on the metabolism of nitrogen, calcium and phosphorus in adult human beings was next studied[7]. The results are given in Table V from which it is evident that (1) the average retention of nitrogen on the rice-tapioca diet was almost equal to that observed on the rice diet and (2) the average retention of calcium and phosphorus on the rice-tapioca diet was significantly greater than that observed on the rice diet. It may, therefore, be concluded that 25 per cent of rice in the diet of adults could be replaced by tapioca flour without affecting adversely the retention of nitrogen, calcium and phosphorus.

Feeding experiments on children: Feeding experiments were conducted on children in order to assess the effects of replacement of (1) 25 per cent of rice in the diet by tapioca flour and (2) 50 per cent of cereals (wheat and jowar) in the diet by a blend of tapioca flour (75 parts) and groundnut flour (25 parts), on the growth and nutritional status of children[2,9].

TABLE IV. *Effect of replacing rice and other cereals by tapioca flour or Mysore flour* on the growth of rats*

Main ingredients in the diet †	Protein content of diet (on dry basis) (%)	Average weekly growth (g)
Series I		
1. Raw milled rice 78.5% ...	8.4	4.9
2. Rice 58.9% + tapioca flour 19.6% ...	7.2	7.2
3. Rice 58.9% + tapioca flour 15.7% + groundnut flour 3.9% ...	9.6	9.0
4. Mysore flour 78.5% ...	13.2	10.5
Series II		
1. Wheat 78.5% ...	13.9	9.9
2. Wheat 58.9% + tapioca flour 19.6% ...	10.9	10.2
3. Wheat 58.9% + tapioca flour 15.75% + groundnut flour 3.9% ...	13.6	10.3
Series III		
1. Ragi 78.5% ...	8.9	8.4
2. Ragi 58.9% + tapioca flour 19.6% ...	7.8	7.6
3. Ragi 58.9% + tapioca flour 15.7% + groundnut flour 3.9% ...	9.9	10.9

* A blend of tapioca flour (75 parts) and groundnut flour (25 parts) is also known as 'Mysore flour'.

† The other ingredients in the diets were: red gram dhal (*Cajanus cajan*) 5.0%; leafy vegetables 2.1%; non-leafy vegetables 8.2%; milk powder (skimmed) 0.9%; common salt 0.3%; groundnut oil 5.0%.

TABLE V. *Metabolism of nitrogen, calcium and phosphorus on rice and rice-tapioca diets in adult human beings*

Diet	Intake (g)	Retention (g)
Nitrogen		
Rice ...	9.69	2.65
Rice-tapioca ...	8.93	2.75
Calcium		
Rice ...	0.529	0.047
Rice-tapioca ...	0.586	0.153
Phosphorus		
Rice ...	1.155	0.196
Rice-tapioca ...	1.178	0.470

In the first experiment[8], the children in the rice group received 8 ounces of rice while the children in the rice-tapioca group received 6 ounces of rice and 2 ounces of tapioca flour. The other ingredients in the diets were the same. Height, weight, haemoglobin and red blood cell counts of the blood and nutritional status were assessed at the beginning and end of a period of 6 months. The results (Table VI) showed that there was no significant difference between the two groups in respect of the characteristics studied.

TABLE VI. *The effect of partial replacement of rice in a poor rice diet by tapioca flour on the growth and nutritional status of children*

Characteristics	Average increase in 6 months	
	Rice group	Rice-tapioca group
Height (inches)	0.66	0.68
Weight (pounds)	1.07	1.30
Hæmoglobin (g/100 ml blood)	−0.70	−0.15
Red blood cells ($\times 10^6$/cu.mm)	0.18	0.09

In the second experiment[9], the children in the control group received 9 ounces of cereals consisting of rice 3.2 oz. ragi 1.3 oz. wheat 2.25 oz. and *jowar* 2.25 oz. The experimental group was given 4.5 oz. of a blend of tapioca flour and groundnut flour in the ratio of 3:1 (known as Mysore flour). The other ingredients in the two diets were the same. All the children relished the blend of tapioca and groundnut flours. The experiment lasted for a period of 6 months. The results (Table VII) showed that there was no significant difference between the two groups in respect of any of the characteristics measured except the haemoglobin which showed a significant increase at 5% level of significance in favour of the tapioca groundnut flour diet.

TABLE VII. *The effect of partial replacement of cereals (wheat and jowar) in a poor Indian diet by Mysore flour on the growth and nutritional status of children*

Characteristics	Average increase in 6 months	
	Rice-wheat-jowar diet	Rice-Mysore flour diet
Height (inches)	0.62	0.67
Weight (pounds)	1.70	2.61
Red blood cell ($\times 10^6$/cu.mm)	0.20	0.27
Hæmoglobin (g/100 ml.blood)	0.42	0.66

It may be concluded from the results of these experiments that (1) 25 per cent of rice in the diet could be replaced by tapioca flour without affecting the growth, general health and nutritional status of children and (2) 50 per cent of cereals (wheat+jowar) in the diet could be replaced by a blend of tapioca flour and groundnut flour in the ratio of 3:1, without affecting the growth and health of children.

Large-scale Feeding Experiments with a Blend of Tapioca and Groundnut Flours (Mysore flour)

Large-scale feeding experiments[10] with a blend of tapioca flour (75 parts) and groundnut flour (25 parts) were carried out in distress areas in Kadiri taluq in Anantapur district of the former Madras State for a period of 3½ months during the year 1953. This blend of tapioca flour and groundnut flour was given to the people in the form of gruel. The gruel was prepared by cooking 100 parts of Mysore flour, 20 parts of broken wheat and 12 parts of germinated green gram with the required amount of boiling water. Salt was added according to taste. Each individual attending the gruel centre received daily gruel containing 3.75 oz. of Mysore flour, 0.75 oz. of broken wheat, 0.43 oz. of germinated green gram and 0.38 oz. of common salt. The gruel supplied about one-third the daily requirements of proteins and B-complex vitamins and increased to a considerable extent the intake of calories, proteins, minerals and vitamins in which the basal diet consumed by the people was deficient. The investigation showed that the gruel prepared from 'Mysore flour' was relished by the people attending the gruel centres. There was no complaint of digestive trouble by the consumers. The general health and nutritional status of the children receiving Mysore flour gruel was similar to that of children receiving the gruel prepared out of wheat and rice. It can be concluded from the results of this investigation and also from those of the institution feeding experiments mentioned earlier that both in normal times as well as during periods of food scarcity, a blend of tapioca flour and groundnut flour can be used as a substitute for cereals.

Conclusion

Judging from the present trends of increase in food production and of population[1], there is every possibility that the production of cereals in the several Asian countries will not be able to cope up with the increasing demands of the growing population. The need for finding alternative food sources which can be used as partial substitutes for cereals is being increasingly appreciated by the Governments concerned. Roots and tubers appear to be the most promising sources as they yield about 2-3 times as much calories per acre as cereals. They possess the added advantage that they can be cultivated both as kitchen garden crop and on a field scale. The investigations referred to in the present paper have clearly demonstrated that blends of a tuber flour and low fat oilseed flours could be used with advantage as partial substitutes for cereals. Successful efforts to meet the cereal shortage by increasing the production and consumption of root crops have already been made in Japan, China, Indonesia and Ceylon. This line of approach holds out great possibilities for the future in providing the people with adequate food supplies.

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FISH TECHNOLOGY IN INDIA

By J. R. IYENGAR, K. VISWESWARIAH AND M. N. MOORJANI

(*Central Food Technological Research Institute, Mysore*)

Even though the impetus for fish technological research in India is not what it really should be, a survey of the research during the last decade clearly indicates that this subject is fast gaining importance. In this article an attempt has been made to review the work in this field.

Objective Evaluation of Fish Spoilage

Total volatile bases and trimethylamine can preferably be estimated[1,1 a] by steam distilling an aliquot of the 90 per cent ethyl alcohol extract of the fish sample under reduced pressure. Total volatile nitrogen gives[2] a better index of fish spoilage than the trimethylamine content. The trimethylamine oxide content of 18 marine fishes of the west coast of Madras has been reported[3]. Trimethylamine oxide contents of some of the marine fishes of the coast of Kozhikode have been estimated and compared with the values for related species found elsewhere[4] indicating that the quantity of TMA oxide present in fish may have a bearing on the toxanomical differentiation of the species. It has been shown[5] that the values for total nitrogen, TMA nitrogen and ammonia nitrogen cannot be used as indication for spoilage of fresh water fish. However, a correlation was obtained between organoleptic rating and 'A and B' values of Stansby and Lemon. Changes during storage of fish at 4°C and 30°C in total volatile base (TVB), volatile reducing substance (VRS) and in bacterial count were studied[6].

The estimation of VRS provides a satisfactory test for judging the quality of fresh water fish since the increase is coincident with the onset of spoilage as indicated by organoleptic tests and by bacterial counts. The tetrazolium reduction may prove to be useful as a presumptive test for the detection of fish spoilage in cured fish[7]. Later it has been shown that the presence of 1 per cent NaCl inhibits[8] the reduction of tetrazolium to formazan. Different species of fish, pH of the medium and the incubation period influence the tetrazolium reduction test[9]. A modified method[10] based on the use of 2-3-5 triphenyl tetrazolium chloride has been successfully applied to assess the quality of fresh water fish.

The protein content of fish can be determined from their albuminoid ammonia values[11].

Bacteriological Studies

The normally occurring heterotrophic bacterial flora of the environment near Mandapam is briefly described[12]. Studies[13-15] on the bacterial flora of sea water and marine fishes show differences between the bacterial flora of fishes from tropical water and those from relatively cold water. The bacteria isolated off the Mandapam coast[16] were found to be mostly aerobic. The formation of trimethylamine[17] in fish is influenced distinctly by the nature of the prevailing bacterial flora. The flora of the muscle at 0°C consisted mainly of gram negative aspergenous rods and gram positive spore formers. The paucity of flavobacteria and micrococci at 0° C is reported[18]. Forty bacteria belonging to the different genera are commonly associated with Bombay prawns. Fourteen of the isolates tolerate high concentration (16 per cent) of salt[19]. Bacteria responsible for the spoilage of sharks have been identified[20] and it has been shown that with the exception of *Micrococcus candidus* strain all the isolates were gram-negative rods. The corynebacteria were found to be absent. A later report[21] has, however, recorded corynebacteria on the skin of shark fish. Mackerel preserved in oil develops sulphide stinker due to anaerobic bacteria clostridium[22].

Preservation of Fish

Chemical ices[23] containing sodium benzoate, sodium phenate or sodium hypochlorite, though these suppressed the bacterial load, yet did not increase the keeping quality of fish considerably. Fish stored in ice made with a solution of 0.1 per cent $NaNO_2$ and 1 per cent NaCl kept in good condition for 96 hours. These two chemicals act synergistically in lowering the

rate of spoilage in fresh water fish[24]. The results of investigations of aureomycin ice in the preservation of fish indicate that it becomes beneficial if the storage period is to exceed 7-8 days[25]. Aureomycin had no effect in prolonging the keeping quality[26] of round and eviscerated fresh water fish when stored at 30° C. However, the effectiveness of the antibiotic in prolonging the storage life of fish fillets stored under identical conditions was demonstrated.

Salting

It has been estimated that about 50-70 per cent of the marine fish catches of India are at present being processed into cured products[27, 23]. Only 17.3 per cent of the total fish landing is being cured through the Govt. fish curing yards, the rest being processed in private yards[29]. The methods employed for curing fish are crude and primitive and the product is very unattractive[30, 31]. Gutting of the fish is not universal. Much longer periods for the duration of curing are reported from Travancore lasting up to 4 weeks. Salt is applied in the ratio of 1:5 or 1:6 for large fish and in much lower ratios up to 1:16 in case of the smaller varieties[32,33]. A study[34] of the quality of cured fish products from the west coast of India, representative of different methods practised, indicated wide differences. The poor quality of the cured fish products is ascribed to the defects adopted in each area and to the low sodium chloride content of the salt. The optimum ratio of salt to fish as employed in curing fish at Bombay yards has been determined and it varies for different kinds and sizes of fish and for different seasons of the year[35]. Analysis[36] of salt cured marine fish has shown that its moisture content varies between 40 and 50 per cent. Total volatile nitrogen, not trimethylamine nitrogen, gives a fair indication of the extent of spoilage of salt cured fish. Bacterial counts of cured fish are from 10,000 to 450,000 per gram of muscle. Studies conducted[37] on different aspects of curing of sardines have shown that in sun-dried sardines, the moisture content of the fish has to be kept below 25 per cent in order that it may keep for a sufficiently long period without undergoing spoilage. The optimum period required for fish curing[38] was found to be 2 days in the case of gutted mackerels salted in 1:5 ratio. For the estimation of total volatile nitrogen[39] in cured fish products, it is preferable to prepare an aqueous extract of the sample and to use sodium borate or alkali for distillation. Estimations of red halophilic bacteria, which cause discolouration of fish, have shown that rock salt is free from bacteria, whereas some marine salt samples show high count[40]. Protein content of local cured fish is much lower than fish cured in Government yards[41]. The chemical composition of sun-dried fish has been estimated; the result shows that the value for ash is very high and also for iron, showing extraneous contamination. From every aspect sun-dried fishes are unsatisfactory for consumption[42].

Curing (Pickling)

It has been suggested[43, 44] that 'Malabar tamarind' (from *Garcina-cambogia*) helps in the fermentation of fish in the 'Colombo curing' method. While studying[45] the merits and demerits of using Malabar tamarind and vinegar in pickling fish, it has been shown that vinegar treated sardines are better as judged from taste and appearance and thus the use of vinegar for pickling can be recommended. The organic constituents of Malabar tamarind[46] have been identified.

Semi-drying

Processes[47, 48] for the preparation of semi-dried and hard-dried prawns have been worked out. The preservation of prawns by the process of semi-drying does not alter its food value to any appreciable extent[49]. The amino acid composition as assessed by chromatography shows that both semi-dried and hard-dried prawns contain all the principal amino acids in fairly good amounts. There is a possibility of popularising processed prawns as marketed in Australia[50]. A study to improve the local sun-drying methods of preserving prawns is reported[51]. Storage studies up to one year indicated no signs of fishy odour, moulds or maggots.

Canning of Fish

Canned fish consumed in India is mostly imported. Some Indian firms have recently

started the canning of pomfret and also the production of dry and wet packs of shrimp. The main obstacles in the way of establishing a fish canning industry in the country are irregular supplies of fish, lack of good and cheap containers and short duration of the canning season. The experience of the Madras Government in running a fish cannery at Chaliyam (South Malabar) which worked for 16 years after being opened in 1911 revealed the very many practical and technical difficulties that have to be overcome before fish canning can become a commercial proposition[52].

It has been shown that spoilage in mackerel preserved in oil[53] is caused by the bacteria belonging to the genus *Clostridium*. The effect of storage at different temperatures on the nutrients of canned fish has been studied[54]. The peroxide number of the muscle fat and the covering oil was negligible up to 4 months' storage, after which it increased, the increase being greater at higher temperatures.

Freezing of Fish

The discolouration of frozen pomfrets occur usually after four months of storage. A special moisture-proof-lined gunny sack has been designed in which the fish is kept in good marketing condition for as long as 12 months storage and this method is now being used by the trade[55]. Ordinary gunny sack provides a formidable reinforced glaze because of its high water absorbing capacity. The results of studies on the freezing and cold storage of mackerel[56] have shown that the development of rancidity in stored mackerel appears to be the principal factor for its deterioration. The treatment by trisodium phosphate to store quick-frozen white pomfrets without discolouration is suggested since it is quite suitable and cheaper to fish traders[57]. Eels[58] were quick frozen in baskets after curling them in the form of cylinders as required for transport. It is interesting that frozen eels fetched a price three times more than its purchase price.

Transportation of Fish

The general problems in fish transport[59] and preservation in India have been discussed showing that there is paucity of data regarding the microbiology of fresh-water and marine fish of the tropical region. Treatment of ice containing chemicals has been suggested for short time preservation of fish in India. Development of proper economic containers for transport which protect the fish from physical injury and at the same time act as heat insulators is urgently called for.

Biochemical and Nutritional Studies

Data have been presented[60-71] regarding the chemical composition of both fresh water and marine fish. The results reveal that the fish constitute a good source of nutrition having protein of high biological value and digestibility co-efficient. Prawns[72-73] too form an excellent nutritive article of diet. Distribution of nitrogen and sulphur in the crude proteins in three varieties of fresh water fish has been reported[74]. In the samples analysed, cystein sulphur is found to be very high.

The amino acid make-up of marine fish protein as studied by paper chromatographic technique compares very well with proteins of other animal sources[75-77]. The amino acid make-up was the same in all cases. The absence of tryptophane in sardine group and richness of leucines in pomfret are noteworthy.

The fish protein free from any unpleasant odour prepared from shark and skates is almost completely hydrolysed to soluble components by the action of pepsin. There was some difference in the order in which the amino acids were liberated when casein and fish protein were acted upon by trypsin[78].

A detailed method for the isolation and purification of proteins from fish, free from any odour, has been worked out[79]. The proteins are 85-90 per cent pure. The amino acid make-up of these proteins showed that they contained all the essential amino acids in significant amounts and compare very well with that of casein[80]. The *in vitro* digestibility[81] of some Bombay fish show that almost all the essential amino acids are liberated from the protein by digesting it for 3 hours by pepsin and trypsin.

The amino acid composition of certain Bombay fish have been estimated by paper chromato-

graphic technique[82-83], while others[84-86] have estimated the amino acids by microbiological assay. These investigations have revealed that fish protein contained all the essential amino acids in considerable amounts. The general pattern of amino acid was the same in almost all the fish. The amino acid make-up and rate of release of essential amino acids during digestion *in vitro* have been reported[87] for shark and skate fish muscles.

It is reported[88] that sun-dried Ruhee fish meal has higher biological value and digestibility co-efficient than the steam-dried fish meal. The digestibility and biological value[89] of fish proteins are very high varying between 83-97 per cent and 70-88 per cent respectively. It has been further shown[90] that even at 5 per cent and 10 per cent levels, the biological value of fish proteins of some of the varieties of Bengal fresh-water fish is higher than casein.

Extraction and chemical analysis of proteins of the *Labeo Rohita* and *Clupea ilisa* reveal[91] the difference in the nutritive value of the proteins of the two varieties of fish. Ruhee proteins contain more of sulphur amino acids than the proteins of *Clupea ilisa.*

The effect of boiling and frying on the enzymic hydrolysis of fish protein has been studied. The rate of hydrolysis of fish protein was found to be greater with pepsin than with trypsin.

The protein content of the locally cured fish is considerably lower[92] than that of the fish in Government yards because of rapid bacterial spoilage during slow drying in the sun.

The nutritive value of four types of common Indian diets has been investigated[93] by studying the influence of these diets on intestinal thiamine synthesis. Bengali rice-fish diet showed poor nutritive value. The use of Indian chank (*Xancus pyrum*) has been advocated[94] because of high percentage of protein similar to that of fish. Data are presented[95] for the phospholipid content of the brain and muscle of 22 varieties of fish and the results indicate that the muscle varied in its lipid content. The properties of thiaminase occurring in varieties of Brackfish, salt fish and marine fish have been investigated[96]. The distribution of NPN in some marine fish and some invertebrates have been studied[97]. The free amino acids have been used as spoilage indicators[98].

Fish Meal and Fish Flour

On account of the widely variable composition of fish meals, it has been suggested that fish meals should be blended and graded before being issued as stock feed[99-100]. Fisheries Department of Madras has now standardised[101] fish meal production of uniform quality containing 50-55 per cent protein content guaranteed and tested before supply. The newly erected fish meal plant at West Hill has augmented supplies to such a considerable extent that the Fisheries Department has now come forward to meet any quantities of local or foreign demand at the competitive price of Rs 750 per ton wholesale or at 50 nP. per pound retail. The probable causes[102] for rapid deterioration of the meal stored in gunny bags may be attributed to the higher humidity of the atmosphere which is responsible for increase in the moisture content of the meal, thus favouring bacterial, fungal and insect growth.

A method[103-104] has been developed to ferment minced fish flesh in the presence of defatted milk and subsequently treated in the same way as in reduction processes. The method is found to be particularly suited to Elasmobranch fishes where the body oil content is very low and the removal of the high flesh urea content presents a major problem. Fermentation almost completely eliminates urea and partially deodorizes the product. This product does not impart fish flavour to food preparations when quantities up to 15 per cent by weight of the flour are used. Fish can be effectively preserved by blending fish flesh with a starchy material containing Tenox II and drying the resulting vermicelli in a current of hot air[105]. The fragile or brittle nature of the finished product has been overcome by partial gelatinization of tapioca flour with hot water and incorporation of wheat semolina. The finished product is cheap and highly nutritive containing 20 per cent protein of high biological value. The process can be adopted on a cottage scale.

Fish Hydrolysates

Fermented liquid preparations from fish, though uncommon in India, are commonly used in the South-East Asian countries. The maggi sauce used in Europe is similar in preparation and

properties to the Nam-pla of Thailand, Patis of the Phillippines and the Uocman of Indo-China. Nam-pla has been shown by analysis to be essentially a protein hydrolysate.

A product similar to the preparations from south-east Asian countries has been prepared[106-107] using sardines. Fish hydrolysate in the form of powder has been prepared having 85 per cent protein content and its amino acid content comparable with that of other food products[108].

Fish Liver Oil

The potentialities of the shark liver oil industry in India have been discussed[109]. The data for vitamins C and D contents of liver and body oils of a large number of Indian fish have been compiled[110]. In a review[111] is recorded the vitamin A content of the body and liver oils of 36 varieties of marine and 62 varieties of fresh water fish occurring commonly in Bengal waters. Steaming and centrifuging[112] gave better yields as well as better vitamin A value for the oil. Vitamin A potency of oil which oozes out from shark livers by low pressure shows only 6.33 per cent of the concentration of vitamin A obtained by steam extraction[113] which might be due to the existence of a complex of vitamin A with proteins in liver such as have been shown to occur in the visual purple and in the mucosa of the intestinal tract. The vitamin A content of Indian fish liver oils has been estimated[114].

Considerable seasonal variations occur with *Labes rohita;* its mescentric fat contains no vitamin A. The relation between dilution of the oil and the intensity of the colour in the Carr Price method is discussed[115]. The vitamin potency of hilsa liver oil[116] is equal to that of halibut liver oil. The methods of vitamin A assay, tintometric, spectrographic and biological, give fairly concordant results[117]. The vitamin A potency of the liver oils of ruhee and hilsa fish is reported to be[118] 461 and 120 I.U. per g. as determined by the biological method. Employing the spectrographic method for vitamin A, some of the Indian fish liver oils tested[30] were more potent in vitamin A than Norwegian fish liver oil[119]. The liver oils of most of the fish examined proved to be exceedingly rich in vitamin A[120]. These values are indeed comparable to halibut liver oil (48,000 I.U. per gram). In this connection, curiously enough the values obtained by Basu *et al*[121] were very low. The vitamin A content of 15 different varieties of fish found in Bombay coastal waters has been investigated[122] in details describing the size of fish, the weight of livers and the yield of oil. 37 different samples of shark and raw fish liver oils were found[123] to contain on an average vitamin A values to be 13,600 and 8,000 I.U. per gram of the oils respectively. The average vitamin A content of 28 different samples of shark and saw liver oils is 10,000 I.U. and 12,000 I.U. per gram respectively[124]. A sample of shark liver oil[125] contains 190,000 I.U. of vitamin A per gram as estimated by the spectrographic method. The liver oil of small shark belonging to Carchrias species is exceedingly rich in vitamin A. Values as high as 171,500 I.U. of vitamin A per gram have been estimated on the basis of colour reaction with $SbCl_3$. It would appear that this oil contains nearly 50 per cent pure vitamin A[126]. No relationship could be established[127] between the vitamin A content and the physical and chemical properties of 12 varieties of oils. The shark liver oils studied showed close similarity for chemical constants, but the vitamin A potency was very variable[128]. Liver oils of Dahin, Vetki and Sankachur[129] were examined for vitamin A potency and found to be generally poor as compared to cod liver oil. The Carr and Price values for a few fish liver oils have been recorded[130]. The ratio between blue units and International Units of biological value of the liver oils of Mushi and Ghol was found[131] to be 4.2. The seasonal variation[132] in the yield of oil and the vitamin A content of 4 varieties of fish *viz.*, Mushi, Waghi, Shengti and Ghol show that the yield of oil varied from month to month in all cases. The liver of some 15 common fresh water fish of Punjab[133] have been found to be rich sources of vitamin A. Sharks caught from the Bombay coastal water showed[134] 8000 to 200,000 blue units of vitamin A per gram, and 1000 to 5000 vitamin D I.U. per gram of liver oil. Oil obtained from the Viscera appear to be even richer in vitamin A. Wide variations in oil content and vitamin A potency[135] were observed when the 2 lobes and different regions of the same lobe of shark liver

were examined separately. The range for oil content was 3.5—11.4 per cent and for vitamin A 4.2—98.9 per cent. The vitamin A content and other analytical characteristics of 28 shark liver oils[136] have been recorded. Acetyl values increase with the F.F.A. content of the oil. Oils with high acid values, had correspondingly higher acetyl values. The seasonal variation in vitamin A content of fish liver oils has been investigated[137]. The characteristics, compositions and vitamin A content[138] of liver oils of different species of Indian fishes have been reported.

The extent of absorption of vitamin A from different fish liver oils by rats was found to depend on the source[139]. The liver oil from the brackish water fish Boleophthal species in the deltaic region of the Godavari is largely consumed in place of ghee, and curative and rejunevative properties are attributed to the oil by the local population[140].

The spectroscopic method for the assay of vitamin A was exhaustively investigated including the calibration of spectrophotometer, determination of spectra in various solvents and interference due to related substances[141]. The problem of determining vitamin A has been generally reviewed. Vitamin A values estimated both by spectrophotometric and glycol dichlorhydrin methods in 10 samples of liver oil[142] ranged from 1000 to 32,900 I.U./g. The spectro-photometric values of $E^{1\ \text{per cent}}_{1\ \text{cm}}$ (gross) $\times$ 1600 and $E^{1\ \text{per cent}}_{1\ \text{cm}}$ (corrected) $\times$ 1910 (cyclohexane) at m_μ 238, for vitamin A do not agree in the samples of fish oils[143] which undergo oxidation and deterioration during storage.

The vitamin A_1 and A_2 contents of Indian marine and fresh water fish liver oils were analysed spectrophotometrically[144]. Vitamin A_1, vitamin A_2 and neo vitamin A contents of some oils have been determined[145-147]. Most of the vitamin A_2 in the liver oils of fresh water fish is found to be in the ester form, while vitamin A_1 existed as alcohol[148]. Shark liver oil has 10 times the vitamin A content of cod liver oil[149].

Carchrias Limbatus (Pisori), *Castraction Blochii* (Kan-Mushi), Washberr *and* Khader Mushi, liver oils have been fractionated[150-151] by low temperature crystallisation, fractional distillation of methyl ester and alkali isomerisation of unsaturated fractions for their component fatty acids. Fractionation of fatty acids from Indian shark liver oils by urea adduct elution technique using aqeuous alcohol of varying strength for elution presents a novel method of graphical integration for calculating the gross composition of marine oils[152]. Lithium salt-acetone and lead salt-alcohol methods in combination with urea[153] fractionation of soluble salts have been developed for obtaining the concentrates of varying degree of unsaturation from Indian elasmobranch shark liver oils. The fatty acids of visceral oil of fresh water fish 'Chital'[154] have been estimated.

A detailed study[155] describes concentration of vitamin A by molecular distillation, stability of the vitamin and deodorisation of the oil. Liver oil deodorised by agitation with fermented milk or toddy remains bland for several months[156]. A simple, portable and economical liver oil extractor capable of handling 5-100 lbs. of liver has been designed[157].

The development of peroxide[158] in shark liver oil and the attendant destruction of vitamin A at various temperatures shows that there is an induction period which varies with different samples of oil and in which the formation of peroxide was slow. Copper, mild steel, nickel, stainless steel, aluminium, tin and zinc—all catalyse the oxidative destruction of vitamin 'A' in samples of shark liver oils in the order given[159]. After the termination of the induction period, the destruction of vitamin A proceeded as rancidity developed[160]. The presence of moisture augments the oxidative rancidity while free fatty acids act as mild catalysts in the oxidation of the glycerides and the vitamin. The induction period as determined by the formation of peroxides was increased when the oil was mixed with freshly refined groundnut oil[161]. High free fatty acid contents not only adversely affected the keeping quality of the unfortified oil, but also lowered considerably the effect of the added antioxidants. Freshly extracted oils of low acid value (preferably below 1) respond better to the action of anti-oxidants studied[162]. The protective action of anti-oxidants is destroyed by the combined action of moisture and free acid. Exposure to direct sun light caused enormous destruction in vitamin A and anti-oxidants were incapable of

retarding this strong destructive action[163]. Development of peroxides and destruction of the vitamin normally run parallel. However, at elevated temperatures or in presence of traces of catalysts, the peroxides are decomposed, although vitamin destruction is still greater[164].

Hilsha (*Clupea Ilisha*) fish liver[165] is a very poor source of vitamin B_2. The extraction of vitamin B_2 from liver is stated to be optimum at pH 5. Of the fish bodies investigated, those of Rohit, Parse, and Tangra are rich in vitamin A; however, they cannot compare with fish liver oils in their potency for vitamin A[166].

The tissues in young fish are richer in vitamin C, than the corresponding tissues of a bigger fish of the same species[167].

Vitamin D potency[168] of the oils of a few common fish of Bengal was found to be 0-52 rat units and 0-93 chicken units per gram. Values on the whole, are very small as compared to the antirachitic potency of cod liver oil. Crystalline vitamin D[169] has been isolated from the oil of Notoptenes chital; the properties of the crystals agree fairly closely with those of calciferol. 14 samples of shark and saw fish liver oils[170] on an average contain 200 I.U. of vitamin D. Since shark liver oil is diluted before being marketed, it is necessary to fortify it to bring it up to the B.P. standard for cod liver oil. The vitamin D content of the liver oil of Mushi and Ghol was found to be 97 I.U. and 575 I.U. per gram respectively[171]. The Indian shark liver oils have been shown to be very poor in vitamin D[172].

The liver fats of some of the species of fish have been found to have a high content of saturated fatty acids[173-176].

Dry shark liver residue has been used for the preparation of proteolysed extracts[177], using crude papain and crude pancreatin. The extracts have been analysed for vitamins. The important enzymes[178] of some elasmo branch fishes with particular reference to the characteristics and distribution of proteinases in different organs have been studied. The possibility of extracting vitamin A on an industrial scale utilising the livers and viscera of Dara fish has been indicated[179].

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CHEMISTRY AND TECHNOLOGY OF FRUIT AND FRUIT PRODUCTS —CHEMICAL ASPECTS

By J. S. Pruthi, S. Ranganna and Girdhari Lal
(*Central Food Technological Research Institute, Mysore*)

In India, during the last 30 years, considerable amount of literature on the chemistry and technology of fruits has appeared in different scientific and technical publications. It is the purpose of this paper to review the consolidated literature on the chemical aspects of the subject to-date.

1. Carbohydrates

Employing paper chromatographic techniques in conjunction with suitable chemical methods, the carbohydrates occurring in a number of fruits and fruit juices have been investigated[1-10]. Glucose, fructose and sucrose are the common sugars in citrus fruits, banana[1], mango[2], pineapple[2,3] apple[2], papaya, passion fruit[2,4], guava[2], tender kernel of palmyra palm[5], *amla*, sapota[6] and *kamarkh*[7], but only glucose and fructose are present in *Jaman* (*Eugenia jambolana*)[8], grapes[2], cashew apple[2], pomegranate[2-6], *phalsa* (*Grewia asiatica*) and black plum[9]. Mangosteen and apple juice, contain in addition, arabinose[2]. Ten varieties of banana[10] at their ripe stage, have been found to contain 7-8 sugars, four of which are maltose, sucrose, glucose and fructose. However, *Maduranga* variety of banana contains glucose only[10]. None of the fruits examined[6] contained maltose as reported by others[9-10]. The occurrence of a polysaccharide (amylopectin) in passion fruit juice[4], galactomannan in tender kernel of palmyra[5] and an oligo-saccharide in *phalsa* (*Grewia asiatica*) have been reported. Papyrographic characterization of sugars in some wild fruits of Nainital have been studied[10a].

2. Organic Acids

Of the citrus fruits examined[11], lemon contains the highest amount of citric acid and surprisingly high proportion of oxalic acid, while pomello contains only oxalic acid and no citric acid. Orange (*C. sinensis*) contains citric and malic acids while lemon contains citric, malic, oxalic and succinic acids[11]. Ripe fruits of *Citrus acida*[12] contains citric and malic acids while immature fruits contain only succinic acid.

An acid variety of pomegranate contains mainly citric acid and traces of oxalic acid[11]. Tamarind[11] contains tartaric acid (88 per cent) and malic acid (12 per cent). Unripe grapes contain tartaric and malic acids in equal proportions[11]. *Phyllanthus emblica* (*amla*) contains high proportion of citric and malic acids with low percentage of oxalic and tartaric acids. While *Phyllanthus simplex* contains only oxalic acid[11], *Averrhoa carambola*, Linn., is reported to contain only malic acid. Lewis *et al.*,[7] have reported oxalic (0.16 per cent) and malic acid (0.06 per cent) in the sweet variety and only oxalic acid (0.51 per cent) in the sour variety. The free organic acids present in passion fruit juice (*P. edulis*, sims.) are citric and malic acids, the former comprising about 95 per cent of the total acid make-up[13]. *Eugenia jambolana*[8] has only malic acid (0.59 per cent), while the nine varieties of banana[14] examined have citric and malic acids in both ripe and unripe stages. Oxalic, citric, malic and succinic acids have been identified in unripe mango[15,16], while two acids still remain unidentified. With the progress in salting of mango slices, total acid content of slices came down by over 50 per cent, but the lactic acid content which is nil in fresh mango slices increased with storage[16a]. Recent work shows the absence of lactic acid in salted mango slices, suggesting the absence of lactic fermentation during salting and pickling process[16].

3. Nitrogenous Substances

Fruits, in comparison with the vegetables, contain fewer amino acids[6]. Among the fruits examined[6], *amla*, Coorg orange, pomegranate and *sapota* have the least number of amino acids. Arginine, asparagine, cystine, histidine, proline, and tyrosine occur in traces in a few of the fruits, but none of them contains leucines (except banana), lysine (except custard apple) methionine, phenylalanine, tryptophan or valine.

The number and nature of free amino acids in citrus fruits seem to vary with the variety. Thus, Coorg orange juice, in contrast to *Sathgudi*

variety, has less number of amino acids but no proline. The authors[6] suggest that this difference in two varieties could perhaps form a basis for detecting the type of juice used in products like squashes. They have also reported the presence of glycine in these citrus fruits for the first time[6].

Papyrographic studies[17] on the non-protein nitrogen fractions of four varieties of mangoes, revealed a decreasing order of richness in ninhydrin-positive substances in *Malgoa*, *Raspuri*, an ungrafted variety and *Alphonso*[17]. Fifteen amino acids have been identified in mango seed kernel[18]. Recent studies[19] on the amino acid contents of mango seed kernels of four varieties of mango reveal that all the common essential and non-essential amino acids are present in fairly balanced proportions. However, the amounts of tryptophane, tyrosine, threonine and methionine are somewhat low[19]. There is no significant difference in the quantitative distribution of amino acids in the four varieties[19].

Though the total protein in banana is low, its quality is quite satisfactory[19a]. All the amino acids except threonine-glutamic acid are either equal to or higher than those in casein[19a].

The free amino acids in papaya latex[20] and tamarind pulp[21] have also been reported. A biologically complete protein *anacardein*[22] has been isolated from the fat-free cashewnuts (yield 17-18 per cent). The results of paper chromatographic analyses show that the globulin—'*anacardein*' isolated from cashewnut contains 16 amino acids and their amount present in 100 g. of protein are given[22a].

4. Pectic Substances

Preparation, purification and composition of pectin recovered from a number of Indian fruits have been reported[22-27]. On hydrolysis, pectins from citrus rind, apple, wood apple, country pears and guava were found to contain galacturonic acid, d-galactose and d-xylose; wood apple contained in addition 1-rhamnose, and wood-apple and safflower tops, d-glucose[27].

Paper chromatographic studies on pectin from tamarind pulp[28], passion fruit skins[29] and guava[30], have been made. Tamarind pulp pectin is reported to be rich in galacuronic acid[28] (81.3 per cent) as compared to the low values (14.3 per cent) reported earlier[23], and reported to be a true pectin[28] unlike seed polyose[31-36] which contains no galacuronic acid. The fundamental differences in chemical composition between polysaccharides and fruit pectins have been demonstrated[31-36]. Savur[36b] obtained three polyoses from the tamarind seed kernel one polyuronide and two polysaccharides, both the fractions differing in their solubility and jellying power. The xylan fraction isolated from decorticated tamarind seed is devoid of arabinose[36b] and consists of about 80 ± 5 d-xylopuranose units linked through 1:4 position and disposed in a single branch structure with bifurcation involving the hydrozyl group on C_3 of one of the xylopyranose residues. The molecule consists of one reducing and two non-reducing terminal groups[36b].

5. Plant Pigments

(*a*) *Anthoyanins and Related Compounds:* The purple pigment in the fleshy pericarp of *Jaman* fruit (*Eugenia jambolana*) was first identified to be cyanidin diglucoside[37], but later on Venkateswarlu[38] suggested the possibility of cyanidin rhamnoglucoside, while recently Sharma and Seshadri[39] found cyanidin glycoside, petunidin and malvidin. Glucose and small quantities of galactose were shown to be present. No pentose or rhamnose could be identified[39].

The occurrence of cyanidin diglycoside in *litchi* fruit, malvidin monoglycoside in red apple, peonidin monoglycoside in black grapes and malvidin pentose glycoside in pomegranate have been reported[39]. Pelarogonidin in passion fruit skins[40], chrysanthemin in red tamarind pulp and a leuco-anthocyanin in the tissue of green tamarind berry[41] have also been identified. The major anthocyanin pigment in concord grape juice is oenidin-3-monoglucoside[42].

Two tannins have been isolated from the Indian gooseberry[43] (*P. emblica*), one containing gallic acid, ellagic acid and glucose and the other containing only ellagic acid and glucose. The former has a protective action on ascorbic acid against atmospheric oxidation, while the latter, which resembles commercial gallotannin, has no such protective action[43]. By means of paper chromatographic studies[44-45], *amla* has been shown to contain some 13 separable tannins, in

addition to 3 or 4 collodial complexes[44]. However, only one tannin has been reported in extracts from small gooseberry (*P. niruri*)[45]. The occurrence of leuco-anthocyanins in raw guava, unripe pomegranate, unripe plantain and small gooseberry have been indicated[45]. The basic nucleus of the leuco-anthocyanins has been characterized in each case[45], the anthocyanin residue being delphinidin in small gooseberry, cyanidin in pomegranate, delphinidin and cyanidin in guava and plantain.

(*b*) *Carotenoids:* The nature of carotenoid pigments in ten varieties of mangoes[46-47, 47a], fourteen varieties of Indian oranges[48], one variety of passion fruit (*P. edulis*)[49], Valencia orange juice[50] and in different varieties of common fruits[51] (peach, papaya, apricot, pineapple, banana, mango, guava, musk melon, water-melon, grapes and mosambique oranges) has been studied. Three out of the five pigments detected in mango have been identified as xanthophyll, β-carotene and pseudo-α-carotene[46], β-carotene being the major pigment[47]. The pigments identified in different varieties of oranges[48] are xanthophylls, kryptoxanthin, neo-kryptoxanthin, α-carotene and β-carotene which, unlike mango[47] or passion fruit juice[49], forms only a very small percentage of the total carotenoid pigment make-up[48, 50], while kryptoxanthin is found to be the predominent pigment. The occurrence of phytofluence, α - β- and zeta carotenes in passion fruit juice have been reported[49].

6. Vitamin C

Of all the vitamins, vitamin C in fruits[52-82] has been studied in great detail. The various fruits covered are *amla*[57-64b], guava[64b, 65-68], mango[69-73a], *amte kayi* (hog plum)[74], *neera* from date palm[75-76], passion fruit juice[77] and other fruit components[77], jack fruit[78], citrus juices[79-82], and other fruits[83]. *Amla* and guava are rich sources of vitamin C. The increase in ascorbic acid during boiling of some fruits has been reported to be due to the presence of combined ascorbic acid[84]. The recovery of ascorbic acid from fruits by using suitable adsorbants has been suggested[85-86]. The existence of a protecting and an oxidising mechanism in plants have been reported[87]. A large number of substances like oxalic acid, xanthine, uric acid, theophylline, creatine, antipyrine and albumen, commonly occurring in plants exert a protective action on ascorbic acid[87-88]. Further, the protective action of pyrophosphate on the catalytic oxidation of vitamin C by copper, norrit, copper-albumen complex and by ascorbic acid oxidase have been reported[89].

Ascorbic acid, carotene and other vitamins in processed fruits have been reviewed[90].

7. Enzymes

The juices of pineapple, *Ficus bengalensis* and *Calatropis gigentia*, which are the reputed sources of proteinases, contain glutathione—natural activator of proteinases[91]. The enzymic redox system in the latex of *Carica papaya* has been reported[92]. The rate of activation of papain by sodium thiosulphate has been further increased by the incorporation of 8-hydroxy-quinoline[93]. The nature of papain activity has also been studied[94]. The mode of action of the anticoagulant factor present in the latex of *Carica papaya* has been investigated[95]. The papaya latex is rich in SH compounds (about 2 per cent) and about one tenth of it is glutathione[96]. It has further been shown that SH group is not necessary for the gelatinase activity of papain but is essential for the peptonase activity[97]. Antibiotics like allicin and penicillin have been reported to inhibit the activity of the milk-clotting enzymes in papaya and fig[98]. The authors[98] suggest that this inhibiting property of the above antibiotics could provide a quick and accurate method for their microassay. Further, the preparation and properties of rennet from fig have also been reported[99].

The changes in catalase, peroxidase and haemin Fe content of mango during fruit setting and ripening have been reported[100]. A distinct correlationship between the catalase and peroxidase activity of the fruit and the haemin Fe content of the tissue has been observed[100].

The other aspects covered are the effect of processing on the trypsin inhibitor[101] in jack fruit seeds, the thermal stability of allinase and enzymatic regeneration of flavour in odourless garlic powder[102], the method of purification and properties of the dehydroascorbic acid reductase in *neera* from date palm[102a], and the effect of

blanching non-enzymatic browning in green *amri* apple[103].

8. Chemical Composition

The chemical composition of several fruits has been reported[33, 104-109]. Varietal differences in the composition of oranges[79-81], mangoes[47a, 113-115a] pine apples[110], passion fruit[111], apples[112] and guava[30, 116], have been studied.

The biochemical changes during the ripening of guava[30, 116-117], sapota[116, 116a], grapes[118], mangoes[47a, 115a 119-120] passion fruit[49, 121] and papaya[122-123] have been investigated in detail. The study of the rate of biosynthesis of different carotenoids in mangoes[47a, 120] showed that β-carotene increased at a greater rate than other carotenoids, while unlike tomatoes and leafy vegetables[120], xanthophyll showed only a slow increase as the fruit ripened. In papaya, the extraction of papain did not significantly affect the quality and recovery of pectin[122-123]. The optimal stage of picking of papaya for pectin recovery is reported to be 108 days after fruit setting[122].

In studies pertaining to the biosynthesis of citric acid in *Citrus acida*, it has been found that citric acid increased with the increase in diameter of the fruit[123a]. In early stages of growth, mostly succinic acid with small quantities of two other acids still to be identified, is present. Fruits of 1.5 cm. diameter contained citric acid with small amounts of malic acid[123a].

9. Bitter Principles

A convenient method for the isolation of bitter principles in the peels, rags and seeds of Indian Shaddock has been worked out[124]. The peels and rags contain naringin 0.13 and 1.0 per cent, whereas seeds contain naringin (.15 per cent), limonin (1.0 per cent) and a mall quantity of isolimonin[124]. The seeds of *C. decumana* contain two isometic principles—limonin and neo-limonin $(C_{26}H_{30}O_8)$[125]. The occurrence of hesperidin in peels and rags of *C. aurantium* and *C. medica* and naringin in the corresponding parts of *C. decumana*[136] has been reported. A new substance *aurantin*—a completely methylated compound of the type of *tangeratin* and *nobiletin*—has been isolated from the peels of *C. aurantium* by extraction with ligroin[126-127]. The rags of *C. limetta* contain limonin as the only bitter principle[128]. Some properties of limonin and isolimonin have been studied[124]. The subject of bitter principles in citrus fruits has been reviewed[129].

10. Other Chemical Constituents

The occurrence of *a-artostenone* in the jack fruit (*Artocarpus integrifolia*) tree latex and jack fruit gum, in the form of enol-wax-estershas been reported[130]. By means of goniometer and X-rays, the morphological examination of the crystals of the stenone and artostenone isolated from jack fruit have been made[131].

The juice of the pericarp of cashew apple contains anacardiac acid $(C_{22}H_{32}O_3)$ and an allied product cardol[132]. The former has been established as a salicylic acid derivative[132]. Pure cardol has also been isolated from the cashewnut shell liquid[133].

A crystalline substance—*Carpasemine* $(C_8H_{10}N_2S)$—a benzylthiourea, isolated from papaya seed, its chemical properties and degradation products have been reported[134]. Two fractions from papaya latex have been isolated, one of which accelerates the coagulation of blood and the other prevents clotting of blood[135].

11. Non-Enzymatic Browning

Non-enzymatic browning in foods has been studied by employing model systems: organic acids-amino acids[136], and sugars- organic acids[137]. Browning in some preserved fruit products[138] and the effect of added ascorbic acid, amino acids and minerals on browning in Coorg orange juice and squash[139] have been studied.

12. Analytical Methods

Several modified methods have been suggested for the estimation of peroxidase activity[140-142], carotene[143-144], ascorbic acid[145-153], moisture[154], juice content in citrus beverages[155-156] and for the identification of food colours[157] and coal-tar dyes[158], a quick field method for the estimation of starch in banana pseudostem[159], a rapid method for determination of calcium and magnesium in plant materials by titration with disodium ethylene-diamine tetra acetate[160] and modified poten-

tiometric determination of ascorbic acid in fruit and vegetable extracts[161].

Concluding Remarks

While a large amount of work has been done on various chemical aspects of some fruits, there is still considerable scope for further research work on the chemical and biochemical aspects of indigenous fruits like mangoes, *amla*, custard apple, cashew apple etc. The chemistry of bitter principle in custard apple pulp, mandarin orange juice and other citrus fruits, the nature of acrid or astringent principles in *amla*, passion fruit skins and cashew apple is yet to be studied. The nature of pectic substances in country pears, wood apple, and jack fruit and nitrogenous substances in some fruits have not still been thoroughly investigated. The chemistry and nutritive value of cannery wastes like mango seed kernel, banana peel, pineapple skins and crowns etc., are also to be studied. Likewise studies on the nature of enzyme systems in some commercially important fruits like mango, cashew apple, passion fruit, *amla* etc., need more attention. The occurrence of pectic enzymes, oxidases, and other enzymes which considerably influence the technological processes need special attention. More detailed studies on the physico-chemical variations in different varieties of commercially important fruits grown in different regions of the country will provide basic data required in the selection of suitable varieties for processing.

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CHEMISTRY AND TECHNOLOGY OF FRUIT AND FRUIT PRODUCTS —TECHNOLOGICAL ASPECTS

By Girdhari Lal, J. S., Pruthi and S. Ranganna

(*Central Food Technological Research Institute, Mysore*)

In the previous paper, the research work pertaining to the chemical aspects of Indian fruits has been reviewed[1]. The present review covers the technological aspects of processing of fruits and of the by-products therefrom.

Fruit Juices

Several papers[2-15] have appeared on the preparation, processing and storage of various types of fruit juices. Comparative studies on the effect of different methods of preparation and preservation of citrus juices[2-4] revealed that deaeration and flash pasteurization gave the best results, sulphitation being the next in order of merit. Addition of a small amount of spice mixture together with 5 per cent sugar or blending juice with pineapple juice improved the quality of preserved Coorg orange juice[15]. Benzoation, ascorbic acid and high storage temperature enhanced discolouration in citrus juices[7-8]. Bitterness in the juice from loose jacket oranges could be reduced considerably by lye-peeling segments prior to extraction of the juice[9]. This process has the additional advantage of removing some of the pectic substances which otherwise cause gelation in the juice or in the concentrate[9] prepared therefrom. Studies[10] on the optimal harvest time of Coorg oranges reveal that oranges picked after middle of January yield juice practically free from bitterness. Nineteen varieties of apples grown in Kulu valley have been examined for their suitability for juice making. Two varieties[11] *viz.*, *Baldwin* and *Yellow Newton* have been found to be the best. The filtragol method of clarification of apple juice has given the best results as compared to the pectinol, kaolin or tannin-gelatine methods[11]. Preparation and preservation of juices from pomegranate[12], water-melon[13], cashew apple[14] and passion fruit[5] have been reported. The anaerobic destruction of ascorbic acid in and the absorption spectra of passion fruit juice packed in different containers and stored at different temperatures have been studied[15]. Losses in SO_2 in lime juice during bulk storage at different temperatures have been reported[16]. Curves have been presented for determining the additional amount of SO_2 at different temperatures to make up the loss[16]. The quality standards for South Indian citrus fruits[10,17] with respect to the recovery and quality of citrus juices have been studied in detail.

Fruit Juice Concentrates

Some technological aspects of the manufacture of concentrates from citrus fruit juices, passion fruit juice, jack fruit and cocoanut milk have been studied[10,18-23]. The optimal harvest time for Coorg[10] and Valencia oranges[18a] for the manufacture of orange concentrate and flavour restoration in orange concentrate with orange oil[10,18b] or juice have been investigated. Detailed physico-chemical changes with respect to brix, acidity, pH, viscosity, ascorbic acid, carotene, spectral reflectance, colour and flavour in lemon[18c], orange[18d,19] and passion fruit juice concentrates[20] have been reported. The retention of ascorbic acid in juices from the three varieties of Indian oranges[19] concentrated on laboratory scale to 72° brix *in vacuo* at 50-52° C ranged from 85-90 per cent, while in passion fruit juice[20], ascorbic acid and carotene retention ranged from 90-94 per cent and 94-97 per cent respectively. During commercial scale vacuum concentration of lemon[18c] and orange juices[18d], the losses in ascorbic acid were well within 5 per cent, there being only 2-5 per cent of apparent ascorbic acid in the final concentrates (4-6 fold). *Sathgudi* orange juice concentrates have a much higher ascorbic acid content (300-380 mg. per cent) than Coorg or Nagpur orange juice concentrates (120-290 and 90-120 mg. per cent respectively[19]).

In general, with the increasing concentration, there was a gradual increase in brix, acidity, viscosity and colour, there being no change in °brix/acid ratio, but a slight fall in pH[18c-d,20]. Upto 3-4 fold concentration, the increase in viscosity was comparatively slight but after 4-5 fold concentration, there was a steep rise in

viscosity. As such, only 4-5 fold concentration of fruit juices is suggested[18c-d, 20]. From the spectral reflectance curves, the C.I.E., colour co-ordinates for citrus[18c-d] and passion fruit concentrates[20] have been presented and discussed.

Ascorbic acid retention in orange concentrate[19], during 4 months' storage at 24-30°C., was only 30 per cent, while in spin-pasteurized canned Valencia orange concentrate[18f] stored at 30°C., for 3, 6, 9 and 12 months, it was 92.3, 88.9, 34.8 and 16.7 per cent respectively. Storage of fruit juice concentrates at low temperatures (2-5°C) is suggested[18-19].

Spin-pasteurization—a new approach to the preservation of canned citrus concentrates, has been the subject of a detailed study[21a-c]. Depending upon the nature and viscosity of the product, spin-processing takes one half to one tenth the time normally taken in the conventional stationary processing. Correlating 'z' and F°' values with heat penetration data, a spin-process of $1\frac{1}{4}$ minutes in open steam in a spin-pasteurizer[21c] for cans (202×214) rotating at 150 r.p.m. followed by spin-cooling of cans at the same speed of rotation under water sprays for 2 minutes has been worked out[21a-b]. The principle performance and industrial applications of spin-pasteurizer have been discussed[21c].

The preparation of jack fruit concentrate[22] and cocoanut milk concentrate[22] has been described.

Fruit Juice Beverages

Most of the references deal with fruit squashes (sweetened fruit juice beverages containing a minimum of 25 per cent pure juice) from citrus fruits[24-29], passion fruit[30-31], jack fruit[32-33], mango[34-35] and fruit syrups from *amla*[36], cashew apple[14, 37] and other beverages[39-41a]. The various aspects covered are preparation and preservation of citrus squashes[24, 26], use of manucol in the distribution of fruit pulp in citrus squashes[25], effect of added manucol on the stability of added synthetic colours in orange squash[27], bulk storage of orange squash[28], vitamin C retention in citrus fruit squashes[29], some technological aspects of manufacture[30] of passion fruit squash, stability of added ascorbic acid in passion fruit squash[31] and jack fruit squash[32], physico-chemical changes in jack fruit squash[33] during storage, pilot plant studies and economic aspects of mango squash[34-35], ascorbic acid losses during the preparation of *amla* syrup[36], commercial development of new beverages[37-40], quick sedimentation of lime juice for the manufacture of lime juice cordial[41] and utilization of otenga[41a] fruit (*Dillenia indica*) in the preparation of otenga syrup. The ascorbic acid losses during the cold and hot acqueous extraction of *amla*[36] were 10.4 and 18.4 per cent respectively, while during one year's storage at room temperature the losses ranged from 38-48 per cent. In the manufacture of citrus squashes, the excess of SO_2, if present in the preserved juice, could be conveniently reduced to the desired levels by its oxidation with calculated amounts of H_2O_2 or Na_2O_2 without significantly affecting colour, flavour and nutritive value of the final product[42].

Canned Fruits

The earlier research work pertaining to canning of fruits etc. conducted under special schemes sponsored by the I.C.A.R. at Lyallpur[43-44] and Quetta[45] has been compiled in the form of special reports and bulletins. The scientific data published covers different aspects *viz.*, maturity tests, varietal trials, nutritive value and storage of various fruits like pears[46-48], mangoes[49-55], pineapples[56-57], guavas[58-59], grapes[60-61], oranges[62-65], jack fruit bulbs[59, 66-70], banana[66, 72], apricots[73], peaches[74], plums[75], litchies[76], mangosteen[76], palmyrah palm kernel[77] and muskmelon[78] with other fruits. The other aspects covered are utilization of honey and agave fructose syrup[79] in the canning of fruits and economic feasibility of canned fruits[80-81], etc. Varietal trials in canning of mangoes[53-54] pineapples[57], oranges[63-68], banana[72] and litchies[75], have been conducted. The optimum stage of maturity of pears for canning as determined by a plunger type pressure tester has been defined[47]. The fruit picked at 13-14 lb. pressure maturity, stored and subsequently used for canning, yields the best results[47]. Such fruits are usually available in Kulu valley in the month of August[47]. The canning varieties in mangoes are *Alphonso*[35, 55], *Raspuri*, *Neelam*[55] and *Himsagar*[48a], *Kew* in pineapples[57], *Allahabad variety* in guavas[58], *Pachabale* and

Chandrabale in banana and *Purbi* variety in litchies[75]. *Fazli* mango[49], which is not a good canning variety[49a], could be lye-peeled in 10 per cent solution of a mixture of NaOH and Na_2CO_3 (3:1) at a temperature of 170° F for 8 minutes. It is felt that, such high concentrations of lye may have some adverse effects on the texture and nutritive value of the finished product during processing and storage. Tin content[50] and ascorbic acid retention in canned mangoes and fruit salads[51] during storage have been reported. Addition of acid to covering syrups for canning of jack fruit[69], muskmelon[78], and *Badami* mangoes[55], but not for *Raspuri* and *Neelam* mangoes has been suggested. The method of preparation of canned strained fruit pulps and custards has been standardized[82-83]. The changes in the concentration of anthocyanin pigment during heat-processing of grape juice under controlled conditions have been studied[84]. Storage studies indicated that the period of storage exerted the maximum influence on the deterioration of the pigment as compared to the nature of the gas in the head-space or the exposure of the samples in the dark or to light. The decrease in pigment concentration on processing and storage was more striking in anthocyanin chloride solutions than in the processed grape juice[84].

Jams, Jellies and Marmalades

The entire work done on jams, jellies and marmalades[14, 43-46, 85-90], pertains mostly to their preparation aspects. However, prevention of mould growth in jams and jellies packed in jars lacking air-tight seal has been studied[86]. The preparation of jellies from papaya[87] and from less-known fruits like mangosteen[76], passion fruit (*P. edulis*) skins[88], jack fruit rind[89] and otenga fruit (*Dillenia indica*)[41a] has also been described. The retention of ascorbic acid in guava jelly is not quite satisfactory[90]. It is concluded that though jams and jellies might appear to be the best carriers of ascorbic acid in view of their low pH and protection from oxygen, the loss of ascorbic acid in these products is so great as to make them unsuitable carriers for vitamin C[90]. Some experiments on the preparation of guava cheese have been described[91]. Besides, the distribution of pectin and ascorbic acid in different component parts of guava have also been discussed[91].

Nutritive Value of Processed Fruit

Systematic studies on the effect of processing operations[53, 59, 88, 92-95] and storage temperatures[13, 33, 68, 70-71, 83, 88, 92, 98-100], on the physico-chemical composition of a number of canned fruits and fruit products have been conducted and the results on the effect of canning operations on *Badami* and *Raspuri* mangoes[53], guava[59], jack fruit[59], banana and oranges[66], pineapple and pineapple juice[92, 99], papaya pulp[93] and other fruits[94] indicate that of the vitamins studied, ascorbic acid is the most affected and carotene the least. A greater volume of juice with increased vitamin C could be obtained by quick-freezing of fruits prior to the extraction of juice[95]. Losses in vitamin C during canning of pineapple[99] were earlier reported to be very high (83 per cent) but later studies[92] revealed very low losses (6-9 per cent only). Effect of storage of canned fruits for periods upto one year at room temperature (28-30°C), 37°C. and 43°C[96-101] on the retention of carotene, thiamine, riboflavin, niacin, ascorbic acid, sugars, tin and iron pick up, colour, flavour and general acceptability of a number of canned fruits have been reported. Samples stored at room temperature do not undergo any discolouration or develop off-flavours but at elevated temperatures (37° and 43° C), discolouration, development off-flavour and hydrogen swell formation usually set in. In general, most of the vitamin C is lost during one year's storage at 37° C and 43°C. Thiamin and niacin are only partially destroyed and are retained better in canned fruits than invegetables[94,100]. Effect of heat-processing and storage temperature on the salt-extractability of protein in canned strained fruit pulps and custards (baby foods) have also been investigated[83].

Some animal feeding experiments have been conducted to assess the supplementary value of fresh and processed fruits[101-104]. Detailed studies[102] on the effect of supplementation of poor vegetarian rice diet with passion fruit juice, squash and plain cane-sugar syrup on food intake, growth rate, calcium, phosphorous and nitrogen meta-

bolism in albino rats revealed that poor rice diet supplemented with pure juice produced maximum growth and had beneficial effect on nitrogen, calcium and phosphorus assimilation. There was no significant difference between squash and syrup groups. Studies on fresh and canned jack fruit[103] revealed that replacement of about 12.5 per cent rice in the poor rice diet with canned jack fruit[103b] did not lead to any further increase in the body weight. Jack fruit is essentially a carbohydrate food and as such does not have any supplementary value to the poor rice diet[103b]. Likewise, orange juice and orange juice powder did not improve the growth rate in albino rats[103c]. Further animal and infant feeding trials on strained baby foods (mango custard) have also been carried out[104].

In cases of congestive cardiac failure with peripheral oedema, the subjects on treatment with coconut regimen responded much better as judged by the improvement of clinical signs, weight loss and urinary excretion of sodium[105].

Banana supplemented to the poor rice diet had a favourable growth response and improved the liver store of thiamine[106], but more recent reports indicate that there was no significant difference in the growth rate of albino rats on test and control diets[107]. Feeding trials further indicated that inclusion of banana in the diet lowers the absorption of nitrogen while there is a three-fold increase in the faecal weight which may be due to the high crude fiber content in the banana[107].

Feeding experiments show that vitamin C, in canned guava[108], fresh amla[109] and Indian Shaddock[110] are as completely available as synthetic ascorbic acid. The tissues of the eight subjects tested could be saturated sufficiently with 0.8 to 1.0 mg. of vitamin C per kg. of body weight[108].

By-Products

Several fruits and fruit wastes have been successfully utilized for the recovery of pectin, essential oils, starch or utilized as cattle feed etc.

(*i*) *Pectin:* Good quality pectin has been recovered from citrus fruits[111], elephant apple[112], citrus peel[113], passion fruit waste (skins)[88], guava[113,115,116,124], country pears[113], pomello[113], raw papaya[114,116,120,123], lemon rind[115], apple[115] jack fruit[116,120,122], sweet melon[116], tamarind[116], Indian gooseberry[116], dried orange peel[117], and woodapple[120]. Citrus peel, country pears, guava[113] passion fruit skins[88], elephant apple[112] raw papaya[114], tamarind pulp[119] and jack fruit[120,122] waste have been reported to be good sources of pectin. The recovery of papain and pectin from raw papaya make it an economic enterprise. Tamarind pulp[119] have been reported to be good sources of pectin. Purification, physico-chemical composition, gelly grade and storage properties of some pectins have been studied[88,113,116,119]. An integrated process for the manufacture of pectin, potassium bitartarate, tartaric acid and alcohol from tamarind pulp has been developed[119]. An investigation into the preparation of pectin from raw papaya by aluminium chloride precipitation has shown that concentration of 0.5 per cent $AlCl_3$ in the cold at a pH of 3.8 to 4.0 gives the maximum yield[123]. Yield of pectin from 2nd and 3rd extracts was higher than the 1st or 4th extracts. Storage of pectin extracts without added SO_2 for 4 days at room temperature (20-25° C) did not seem to affect the jelly grade of the pectin[123]. The quality and recovery of pectin in sulphited and pasteurized (canned) guava pulp and the quality of liquid and powder pectin from fresh guavas during storage for 6 months at different temperatures has been investigated in detail[124].

(*ii*) *Essential Oils:* The earlier work[43] pertains to the methods of extraction and cost of production of orange and lemon oils from the Punjab fruits. Since then considerable attention has been paid to the extraction and physico-chemical examination of several essential oils from limes (*Citrus limonum* and *C. indica*[126]), Nagpur mandarin orange (Steam distilled[127-128] and cold-pressed [29-130]), *C. medica* var. *limonum* and *C. medica* var. *acida*[131], Sylhet oranges[132], Coorg oranges[133,138], *galgal* (*C. limonium*)[134], *Karna Khatta* (*C. aurantium*)[135-136], sweet orange, seville orange and grape fruit[137], and other citrus fruits[138-143]. Several factors affecting the yield of citrus oils *viz.*, fruit size, degree of ripeness of fruit, fruit quality, method of extraction and the time lag between picking, mincing and distillation of oil have been discussed[125]. The yield of lime oil amounts to 6-7 lb. oil per ton of fruit[125] and 1 per cent in Nagpur

orange[127]. The chemical constituents of oils from two varieties of lemons[131], Sylhet oranges[132], Coorg orange[133], *galgal*[134], *Karna Khatta*[135-136], seville orange and sweet orange[137] and Bilwa (*Aegle marmelos*)[144] have been investigated. Results of a systematic study on the effect of various factors like stage of maturity of fruit, fruit size, regional variability, method of extraction of oil, type of container, antioxidants, and storage time and temperature etc., on the absorption spectra and other physico-chemical characteristics of Indian mandarin peel oils have been presented and discussed[138]. Oxygen absorption in citrus oils (A.O.M. value) as measured by the manometric technique, in conjunction with the aldehyde value, peroxide value and organoleptic quality has been suggested as a suitable measure of the stability of citrus oils[138].

(*iii*) *Miscellaneous:* The subject of utilization of mango[14] and citrus waste[146] has been reviewed. The other aspects of utilization of waste covered are the recovery and detoxication of seed oil for edible purposes from *Annona squomosa*[147], *in vivo* and *in vitro* studies on the anthelmintic activity of papaya seed[148] flour and roasted nuts from jack fruit seeds[149-150], pectin from passion fruit skins and oil from passion fruit seeds[89], digestibility of passion fruit seed oil and its effect on growth rate, calcium, phosphorus and nitrogen assimilation and on reproduction and lactation in albino rats[88], pectin from jack waste[151], utilization of banana stem for the recovery of starch[152-153] and for growing food yeast[154], essential oil from waste lime pulp[155], citric acid from *C. aurantium*[156], food value[157-160] and manurial value[161] of mango seed kernel, poultry feed from mango and jaman seed meal[162], and fixed oils from the seeds of melon[163], sapota[164] watermelon[165] and Indian Shaddock[166].

Quality Control in Fruit Products

Based on the physico-chemical analysis (conducted at the F.P.O. Laboratory at C.F.T.R.I., Mysore) of over 4500 samples of different categories of fruit products manufactured in the country during the year 1953-54, a consolidated report has been published by the Agricultural Marketing Adviser to the Government of India, which embodies certain broad trends in quality of different types of Indian fruit products[167].

Concluding Remarks

While considerable amount of research work pertaining to the technological aspects of manufacture of different categories of fruit products has already been conducted in different laboratories in India, there is still scope for concentrating attention on more modern aspects of fruit technology in the light of recent advances in the field, some of which have been briefly outlined below.

Greater emphasis is needed on (*i*) the control of quality (particle size) and quantity of pulp in fruit juices, pulps, concentrates, squashes and other beverages (*ii*) enzymatic removal of oxygen from the processed products in air-tight container with the aid of new enzyme preparations like 'Fermeozyme (comprising glucose oxidase and catalase) (*iii*) colouring of fruit products wherever necessary, with newer preparations like 'water-soluble β carotene', which incidentally also enhances the nutritive value of the product and a study on the stability thereof (*iv*) enzymatic debittering of citrus juices (*v*) determination of the optimal stage of maturity of different fruits from different angles of their utilization *viz.*, from the viewpoint of concentrate manufacture, pectin recovery, quality of juice, etc.

The published information on the agitating processing (*viz. spin-pasteurization*) of fruits and fruit products is rather scanty. Systematic studies on this aspect will not only reduce the processing time but will also assist in better retention of colour, flavour and nutritive value. Besides, the use of low-methoxyl pectins in the canning of soft-textured fruits, particularly during their spin-pasteurization forms a special study by itself.

Some of the other aspects which need attention are the formulation of better essences and colours for different fruit products, development of suitable lacquers and sealing compounds for tin cans, economic utilization of cannery wastes from indigenous fruits and the determination of the nutritive value thereof, preparation of low-sugar jellies and other fruit products for diabetic

patients, tapping the indigenous raw material for the economic recovery of pectin and papain from papaya and the commercial exploitation of milk-clotting enzyme (*fiacin*) and *bromelin* from pineapple waste for subsequent use by the remanufacturing trade in the country.

Some of the above lines of research work are already in progress at this Institute.

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CHEMISTRY AND TECHNOLOGY OF VEGETABLES AND VEGETABLE PRODUCTS

By Girdhari Lal, G. L. Tandon, C. M. Parekh and Lakshminarayana Setty

(Central Food Technological Research Institute, Mysore)

Fruits and vegetables preservation industry in India is of recent origin. Only in 1934, Fowler[1] surveyed the progress of research work done in the monograph entitled '*Industrial possibilities of some research work done in India*' and made suggestions for the development of food preservation industry. Since then the industry has attracted the attention of scientific workers in the country. Indian Council of Agricultural Research also started financing a number of sehemes during the same period for fruit and vegetable preservation. In the span of about 25 years, considerable work has been done in the line. The aim of this review is only to consolidate the work done in India on the chemical and technological aspects of vegetable and vegetable products.

Chemical Composition of Fresh Vegetables

Chemical composition of a large number of fresh vegetables has been reported[2, 3, 4, 5]. Carotene content of some green leafy vegetables has been investigated[6, 7, 8]. All leafy vegetables contain chiefly *Beta* form of carotene[8]. Sadana and Ahmad[9] isolated carotenoid pigments from 14 different varieties of carrots and determined their vitmin A potency. In red varieties, the principal pigment is *beta*-carotene constituting about 60-80 per cent of the total pigments. In orange coloured carrots, *alfa*-carotene predominates and comprises about 34-52 per cent of total carotene; while light yellow, pink or violet coloured carrots contained mostly xanthophyll. Lycopene and carotene as the colouring pigments of tomatoes have been isolated[10]. For characterising and estimating individual carotenoid pigments in the ripening of tomatoes, chromatographic technique has been used[11]. Increase in carotene content during ripening has been reported. The vine ripened tomatoes are rich in carotene than store-ripened tomatoes. Lycopene content is not affected by storing tomatoes upto 38° C for a short period[11].

Green legumes have been found to be a rich source of vitamin B_1, while other green leafy vegetables, tubers and roots are only a fair source of this vitamin[12, 13]. Vegetables, in general, have not been found to be a rich source of nicotinic acid[14]. However, they are considered to be an excellent source of choline[15]. Curry leaves and Patel leaves have been found to be rich source of riboflavin[16].

Vitamin C content of vegetables varies with the locality, season, rainfall, manuring and different stages of maturity. Vegetables and other food stuffs from various parts of the country have been analysed for this vitamin[17-23]. In general, vitamin C in vegetables as well as in fruits is more concentrated in the skin as compared to the edible portion[21]. In root vegetables, vitamin C is more concentrated in their leaves. Some vegetables, such as cabbage, cauliflower, etc., on boiling, show an apparent increase in ascorbic acid[24]. Some vegetables also contain 'ascorbigen' *i.e.*, ascorbic acid in combined form[25,26]. 'Ascorbigen' can be concentrated by evaporating, followed by absorbing on active charcoal and eluting with chloroform-alcohol mixture from cabbage juice[27].

Vegetables are generally considered a rich source of iron but available iron content is very poor as compared to many other foodstuffs[4, 28]. The available and the total iron vary considerably and do not display any distinct group characteristics. In general, most of the vegetables contain roughly 40 per cent available iron and, bulk for bulk, they furnish as much as or even more available iron than most of the other foodstuffs[29].

Phytin phosphorous in vegetable is present in very small quantities with a few exceptions such as potatoes, peas, etc.[30]. This may be due to the presence of active phytase enzyme system of vegetables[31].

The presence of oxalic and other organic acids in vegetables has been reported[32, 33]. *Garcini Indica*, which is commonly used in central and west India in place of tamarind was found to contain 10 per cent malic acid and not tartaric acid[36]. Several vegetables have also been investigated for calcium content[33].

Changes in Nutritional Value of Vegetables during Processing and subsequent Storage prior to Processing

Synthesis of carotene appears to continue in some vegetables even long after harvesting and only after considerable storage, deterioration occurs[37]. Leafy vegetables show marked loss of carotene after storage, for one or two days, the loss being more rapid at higher temperatures. In amaranth leaves, when preserved with water containing 3 per cent formaldehyde and stored at 38° C for 3 days, the loss of carotene by air oxidation was very little as compared to those preserved with water under toluene. The loss of carotene can be prevented by keeping the vegetables in inert gas or carbon dioxide atmosphere[37].

Leafy vegetables unlike fruits when stored at room temperature lose vitamin C quickly and this is always accompanied by decrease in acidity. Loss of vitamin C could, however, be controlled or reduced to some extent by storing them at low temperatures. The losses in vitamin C content were more in vegetables when they were stored after ripening[38].

Ramarao and Kadkol[39] observed that non-protein nitrogen, carbohydrates other than starch and thiamine content of field beans decreased with maturity; starch content increased and total nitrogen remained practically constant.

Texture of vegetables is intimately related to the changes in pectic constituents. Pectic constituents of potatoes at different stages of growth, maturity, senescence and during storage have been reported[40]. It has been observed that soluble pectin, protopectin, middle laniella pectin and total pectin content begin to rise during growth but the rate of increase slows down towards maturity and senescence; soluble pectin inreases while other pectin constituents decrease and ultimately rotting sets in during storage[40].

Effect of Processing on the Nutritive Value of Vegetables

Nutritive value is adversely affected by cooking. It has been observed that vegetables when cooked with salt and the cooking medium rejected, there was appreciable loss of minerals and proteins[41].

De[42] observed that corriander and spinach leaves on drying in vacuum even at 100°C did not show any appreciable loss in carotene content. When amaranth leaves were exposed to diffused sun light, a considerable loss of carotene occurred. He concluded that carotenes are relatively stable during processing of vegetables. Their oxidation only takes place in the presence of air and is accelerated by the presence of heat. But heat alone is not responsible for the destruction of carotene. Carotenes are also photo-sensitive.

There is a general belief that frying is more deleterious to nutritive value. Rudra[43] analysed vitamin C content of fresh, fried, cooked and refrigerated samples of cauliflower which contained 101, 67.3, 73.2 and 100.5 mg. per cent respectively. Fresh, boiled and refrigerated spinach contained 123.9, 100.4 and 102.3 mg. per cent respectively. He considers that loss of vitamin C during freezing of cauliflower was, contrary to the common belief, not very high as compared to cooking. In refrigeration the loss of ascorbic acid content of cauliflower even after 15 days storage at 5°C was very little. However, the loss in the case of spinach was slightly higher. Chillies, onions and garlic[44] on cooking lose vitamin C to the extent of about 60, 40 and 55 per cent respectively.

Cooking and storage of foods rich in salt and acid in utensils made of different metals have been reported[45]. Tinned brass and tin-lead alloy vessels were found to be attacked readily. The amount of tin dissolved was independent of the amount of lead present in the alloy. Aluminium vessels were comparatively resistant to corrosion for most of the foodstuffs and were reported to be safe for cooking and storage of food materials[45].

In canned cabbage, 20 per cent ascorbic acid is lost during blanching, 80 per cent when the blanched vegetable is exposed to air and 64 per cent during processing[46]. Chillies and potatoes on blanching for 5 minutes at 95°C, lost 32-33 per cent and 55 per cent of ascorbic acid respectively[47]. Green peas were found to lose 23 per cent ascorbic acid, 16 per cent thiamine, 27 per cent riboflavin and 6 per cent niacin during blanching, while during autoclaving, ascorbic acid loss was 47.5 per cent, thiamine 17.6 per cent and niacin 11.8 per cent[48]. In cauliflower an increase in ascorbic acid from 0.4 to 19.4 per cent

during blanching and 1 to 20 per cent in raw shredded samples kept at 19° to 30°C for 3 hours was observed. Loss of ascorbic acid in cauliflower occurred only during autoclaving for 20 minutes at 10 lb. pressure[49]. Blanching and other canning operations for brinjals, bitter gourd, *okra* and *perwal*[50] showed least damage to protein but loss of mineral content was considerably high. In general, it was observed that blanching of vegetables in hot water causes greater loss of vitamin C and minerals than steam blanching[51].

Tomato juice made by 'Hot-break' method retained more vitamin C than that made by 'cold-break' method[51].

Effect of Storage on Nutritive Value of Processed Foods

Losses in nutritive value of canned vegetables during storage have been reported[46-49, 52-55]. Canned cabbage loses 25 per cent vitamin C during the first week of storage and cent per cent in the course of six months[46]. In canned cauliflower, 19 per cent loss of ascorbic acid was observed during the first week of six months storage. The total loss of ascorbic acid during 6 months was 65 per cent. Addition of ascorbic acid to each can of cauliflower at the rate of 100 mg. per cent after blanching helped in retaining greater percentage of vitamin C during storage[49]. Canned potatoes during the first 4 months of 12 months of storage lost 67 per cent ascorbic acid but subsequent storage for another 8 months showed a slow rate of loss[47]. Canned green peas during 6 months storage showed a loss of ascorbic acid of about 80 per cent, thiamine 29.5 per cent and niacin 47.7 per cent but riboflavin value increased almost to double the original figure during the same period[48]. In bitter gourd, *okra*, *perwal* and *tondale*[52] maximum loss was observed in ascorbic acid content. However, maximum retention of vitamin C was in *tondale*. Major part of these losses occurred during the first 4 to 8 months of storage. Carotene was the most stable of all the nutrients, its retention value being 80 to 90 per cent at the end of 12 months storage. It was also noticed that, in general, retention of vitamin C content in canned vegetables was higher as compared to that in canned fruits for the same period[53]. All types of canned products stored at 37°C and 43°C lose practically all vitamin C content within a period of 12 months. Thiamine and niacin are practically destroyed. Riboflavin and carotene retention in both fruits and vegetables are quite high, about 89 to 100 per cent, during the same period[53]. Stability of natural as well as added ascorbic acid has also been reported. In tomato ketchup, the retention of ascorbic acid was about 28 per cent by the end of one year's storage. The loss was considerably high in partially filled tomato ketchup bottles[54, 55]. Tin and iron content of some commercial samples of fruits and vegetables have also been reported[56].

Vegetable Processing Technology

Uniform maturity of fruits and vegetables for quality products is very important. Suri[57] reviewed the devices generally used for maturity tests of some important fruits and vegetables. Bhatia[58] stressed the importance of enzymatic control during the processing of food products. Das *et al.*,[59] reviewed the role played by antioxidants in the preservation of fruits and vegetables, especially in the control of enzymatic discolouration of cut fruits and vegetables. Adequate blanching of vegetables especially for dehydration is necessary to inactivate the enzyme system[60].

Recent developments in fruits and vegetable processing[61], use of artificial food colours[62] and antibiotics[63] in fruits and vegetables have been reviewed.

On examining 375 commercial samples of fruit and vegetable products, Anand and Johar[64] reported that 20 per cent of canned vegetables were found to be contaminated with spoilage organisms, while Bhatia *et al.*,[65] examining the relative incidence of hydrogen swell formation of canned fruits and vegetables, reported that curried potatoes and also tomato soup even after storing for 27 months did not show any swell formation.

Bacterial load sat different stages of canning of potato, cabbage and peas in the canneries of Calcutta have been reported[66]. Peels of potato carried a heavy load of bacteria which could be reduced by lye-peeling. The high bacterial load in cabbage and peas was observed in blanched and exhausted samples and this might be due to the

presence of high load of resistant bacteria in fresh materials. Micro-organisms responsible for the spoilage of commercial canned peas and cauliflower have been isolated and contamination of the spoilage organisms was attributed to either under processing or cooling process where they might have been breathed into the can along with water[67].

Tender bamboo shoots have been reported for their chemical composition of various varieties and their utilization in the preparation of various preserved products for edible purpose after removal of hydrocyanic acid[68-71]. American varieties of sweet potatoes having orange flesh were found to be suitable for canning in brine as well as for the preparation of dried slices, etc.[72].

Trials on different varieties of potatoes grown in India have been carried out for their suitability for canning[73,74]. It has been reported that O.N. 208 variety belongs to 'Soggy' or 'Waxy' group, while Kerr's Pink could be improved upon by calcium chloride treatment. Mysore Ricket, Phulwa and Darjeeling showed a higher percentage of loss during peeling and trimming and were found to be uneconomical for processing whereas Mysore Ricket and Phulwa could withstand satisfactorily. O.N. 2236 (Patna) potato was found to be a suitable variety for canning after giving the usual calcium chloride treatment[73, 74]. Some varieties of potatoes such as *Solanum chacoense* contain solanine-an alkaloid, in larger quantities than other varieties[75]. It was also found that the concentration of solanine was higher in the peels than in the inner layers of tuber. A method has been standardised for the removal of bitter principals from potatoes prior to their processing[76].

Canning of green chillies gives satisfactory results on adding 0.5 per cent citric acid[77]. The canned product retains its characteristic pungent taste and odour though it does not retain fully the original colour. The retention of ascorbic acid in canned chillies and *Beta*-carotene after $7\frac{1}{2}$ months storage at 24-30°C was 55 and 84 per cent respectively[77].

A method for the preparation of fermented carrot juice known as 'Kanji' in northern India has been reported[78].

'Sutton's abundance' and 'Suttons main crop' have been reported to be the best canners among the varieties of peas tried. Further, the addition of lime juice and sugar enhance the taste and flavour of peas[79]. Modern technique of canning peas, importance of uniform maturity and use of antibiotics for the control of spoilage have been reviewed[80]. The high percentage of alcohol insoluble solids (A.I.S.) as well as starch were found to be responsible for gelatinization of peas which could, however, be avoided to some extent by using larger quantities of brine in cans than the normal quantity[81]. Of various blends of permitted colours tried, the following have been found quite satisfactory in the case of dried as well as fresh canned peas: (*i*) edicol supra blue XS and edicol supra tartrazine N.S. in the ratio of 9:11 or (*ii*) blue V.R.S. and tartrazine in the ratio of 2:8. Peas stored in baskets were reported to be more satisfactory than storing them in bags and boxes. Addition of 0.25 per cent lactic acid to canned peas controlled the gaseous spoilage by *B. lactisacidii*[83].

Canning trials[84] of six varieties of dried peas have indicated that Marrowfat I and II were good canners. Blue round and No. 3 Blue round gave satisfactory results while Tasmania Blue and Yellow round were not suitable for canning. Recent advances in the canning of processed peas have been reviewed[85].

White varieties of gram in the green state were reported to be suitable for canning. The method of canning was the same as for canning of green peas[86].

Varieties of tomatoes evolved by cross breeding such as 'Kulu Valley', 'Sioux', 'Italian Pear', etc[87]., showed better performance for canning purpose. The acidity of tomato pulp varies from 0.4—0.75 per cent and tomato solids varies from 6—7 per cent. The ascorbic acid ranges from 28.5—62.7 mg. per 100 c.c. of juice[88].

In the studies on the mechanism of colour loss in tomato products, it has been observed that copper had a marked effect on the degradation of the natural pigment, lycopene[89, 90, 91].

Preparation of various kinds of tomato products on home as well as commercial scale have been reported[92]. Siddappa and Mustafa[93] standardised the method of canning of tomatoes in Baluchistan. Singh and Lal[94] observed that

varying amounts of oxygen incorporated in the course of tomato juice manufacture affect corresponding changes in the colour of the product from red to dark brown in the bottled pack as in this case the oxygen is free to oxidise the colour which is not fixed by glass. Use of plain cans helps in the retention of bright red colour due to the fixation of oxygen by tin plate.

Technological aspects on the manufacture of tomato juice have been reported and reviewed[95, 96]. Singh and Lal[97] in their studies on tomato juice observed that in tomatoes, the percentage of screened pulp varied from 64—80 with an average of 69.7 per cent with a corresponding variation of 20—36 per cent of wastage due to skins and seeds. The wide range of difference in pulp appeared to be mostly due to the variation in the degree of ripeness and maturity of the raw material used. They also studied the losses of carotene and ascorbic acid during various stages of preparation of tomato juice and found carotene to be fairly stable to the action of heat and oxidation by air during the manufacturing process, while a considerable loss of ascorbic acid occurred particularly when the juice was screened through sieve. In pasteurized juice a comparatively higher percentage of ascorbic acid content was present than in the same juice at the previous stage of manufacture.

Methods for the preparation of tomato ketchup[98] and preservation of tomato juice by suitable combination of preservatives prior to the preparation of tomato ketchups have been reported[99]. Causes of black-neck formation in tomato ketchup were studied and it was found that addition of 100 mg. per cent ascorbic acid prevented the formation of black-neck for a considerable time[100, 101].

Siddappa *et al.*[103] made canning trials on pulses in tomato sauce and standardized the method of removing a beany bitterness from red field beans (*Dolichos lablab*). Lal *et al*[103] found that a variety of bean indigenously obtained from Kashmir, known as 'Earliest of All' was suitable for canned baked beans. It did not impart any beany or bitter after-taste.

A simple method of canning curried vegetables has been standardised and studies also made on the role of pH in the canning of curried vegetables for controlling spoilage due to *Clostridium bolutinum*[104, 105].

Methods for the preparation of strained baby foods, dried as well as canned, have been reported[106].

Methods of canning of various kinds of vegetables are described[107, 108].

The progress of fruit and vegetable research and technology in India during the past 20 years, the present position, research and development work in the fruit and vegetable preservation industry in India have been reviewed[109, 112] in the book entitled *Preservation of Fruits and Vegetables*.

Concluding Remarks

A fairly large amount of work has been done during the past three decades in the country on the chemistry and technology of vegetables and their products, but from the point of canners and preservers in this country a lot remains to be done in evolving a suitable variety of different kinds of vegetables for getting quality packs. At present the industry uses for its requirements the vegetables available in the fresh market, which in most cases are ill-suited particularly for canning. A closeby planned co-ordination between the horticulture and fruit and vegetable preservation organizations in the country is essential to supply to the industry the right type of raw-material for processing. This is not only true in the case of vegetables but is equally important in the case of fruits. With this end in view, ten regional stations in fruit and vegetable preservation are being set up all over the country along with regional horticultural research station of the Indian Council of Agricultural Research during the Second Plan Period so that intensive and extensive studies can be taken up on regional basis to evolve and test suitable varieties of fruits and vegetables for the processing industry in the country.

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INDIAN PRESERVES OR MURRABBAS

By G. S. SIDDAPPA AND M. V. SASTRY

(Central Food Technological Research Institute, Mysore)

The *murrabba* industry in India is one of the most important sectors of the fruit and vegetable preservation industry. Its history is intimately linked up with the indigenous systems of medicine particularly the Unani system. The word *murrabba* is derived from Arabic and means 'preserved' or 'domesticated'. It is generally defined as a preserve made from certain fruits and vegetables applying the principle of high concentration of sugar for preservation. The fruit or vegetable should retain its original characteristics such as shape, taste, flavour, etc. The processes employed are alomst similar to those adopted in the case of well-known candied and crystallized fruits, except that the finished product is packed and distributed in the final syrup itself.

Present Status of the Industry in India

According to a recent report[1] the *murrabba* or preserve industry is concentrated mostly in northern India and nearly 80 per cent of the production is at Delhi and Amritsar. Benares, Lucknow and Calcutta are the other important centres. In 1954, 119 *murrabba* factories out of a total of 662 licensed fruit and vegetable preservation factories, manufactured about 1193 tons valued at Rs. 15.2 lakhs. The Committee has however, estimated an annual production of nearly 3000 tons valued at Rs. 33 lakhs. The

majority of the factories are small ones employing *Bhathies* or ovens for most of the processing work. There is considerable scope for the improvement of the equipment, working conditions and technical control in these small factories.

Method of Manufacture

The present day practice of manufacture of *murrabbas* varies considerably from the indigenous method.

1. *Indigenous method.* In this original method of the Unani system, fully ripe fruit is taken, peeled, if necessary, and cooked in water to make it slightly soft. Then it is taken out and spread for drying. After that it is pricked with wooden or bamboo pricksand placed in thick sugar syrup or honey. Next day, it is removed from the syrup which has thinned down in the meanwhile, and the syrup is heated till it becomes thick again. This process of removing the fruit and heating the syrup is repeated till the syrup does not thin down any longer. The water in which the fruit is first cooked should be utilized for the preparation of the syrup to prevent the loss of valuable constituents through leaching.

2. *Present day method.* In the present day methods of manufacture, two important factors have been taken into consideration, namely, (1) appearance and taste of the product and (2) speeding of the process. To achieve the first object, techniques such as prolonged blanching of the fruit, bleaching with chemicals, use of firming agents like alum and lime, etc., have been resorted to. As regards the second objective, dry sugar instead of syrup is being employed to cut down the number of cookings to two or three only. Further, the system of semi-finishing the product and then storing it for subsequent processing has come into vogue. These expediencies have naturally resulted in certain deleterious effects such as fermentation of the product, etc.

By and large, the following procedure is followed:

The fruit or vegetable like apple, carrot, etc., is prepared by peeling, scraping, etc., and then punctured with brass or stainless steel needles. The fruit is then blanched in boiling water or water containing hyposulphite. It is then drained on baskets, transferred to a trough or vessel, covered with dry sugar and allowed to stand overnight. Next day, the syrup is drained and more sugar added to raise its Brix to 60-75°. In some cases, the fruit and syrup are heated together. At this stage, the product which is considered to have been semi-finished, is generally packed in 4 gallon tins and stored for varying periods depending upon the pressure of work in the factory. There the fermentation takes place and the product swells up due to evolution of gas and fills the entire headspace of the container. Then the fermentation gradually slows down. The product is removed and reboiled with more sugar, cooled and packed finally in the 4-gallon tins. It is believed that intermediate fermentation is essential for softening the texture of the fruit, thereby facilitating the uniform absorption of sugar by the entire fruit. This aspect of the problem, however, requires a critical investigation.

Packaging, Distribution and Sale

The 4-gallon tin is the general pack for wholesale distribution. For retail sale, the product is dispensed from these large containers or from stoneware or earthen jars. Hygienic and sterile packaging in open top sanitary cans has not yet been universally adopted on account of the increase in the cost of packing which would result.

Therapeutic Values of Murrabbas

The importance of many of the well-known Indian *murrabbas* lies in the medicinal and curative properties claimed to be associated with them through long usage. These properties are briefly summarised in Table I. Although precise data regarding the scientific basis for these claims is not yet available, some of them have the sanction of long experience and cannot be easily brushed aside. Systematic work has to be done on this important aspect.

Problems of the Murrabba Industry

The more important problems of the industry are:

(*i*) method of improving absorption of sugar.

TABLE I. *Medicinal value of Murrabbas to the Unani System of Medicine*

Sl No.	Preserve	Properties
1	*Amla* ...	Imparts energy to heart, brain and liver. Stops diarrhoea. A useful remedy for giddiness
2	Apple ...	Stimulant for heart and brain. Relieves physical heaviness. Remedy for paralysis and mental strain.
3	*Harar* ...	A cure for permanent constipation. Imparts energy to stomach and brain.
4	*Bihi* (Quince)	Imparts energy to heart, brain and stomach. A good medicine for mental breakdown, heaviness of body, etc.
5	*Bael* (*Bilwa*)	A good cure for desentry, checks diarrhoea.
6	Ginger ...	Removes congestion in the chest, flatulance; A good remedy for stomach ailments. Gives energy to kidneys, waist. A tonic generally.
7	Ashgourd ...	Imparts energy to heart and brain, acts as laxative.
8	Pear ...	Imparts energy to heart and brain.
9	Pineapple ...	Remedies mental diseases, relieves excess of heat and acts as a tonic.
10	Carrot ...	Imparts energy to heart and brain; clarifies voice.

(*ii*) prevention of fermentation during preparation and storage

(*iii*) discolouration and

(*iv*) data regarding nutritive and medicinal values

Work on these several aspects has already been taken up in our laboratories and useful data collected.

PREVIOUS WORK:

Methods of Preparation

Lal Singh, Girdhari Lal and Sher Singh[2] reported a method for candying *ber* (*zizyphus jujuba*) and orange peel. Tandon[3] described the candying of ginger. Siddappa and Mustafa[4] reported methods for the preparation of preserves and candies from a selected varieties of fruits available in Baluchistan. Siddappa[5] has standardised a conventional as well as a dry-sugar method for making *bael* preserve (*aegle marmelos*). Roy and Verma[6] have described a method for making *bael* preserve. Siddappa and Bhatia[7] have studied the use of honey in preserves. Gupta[8] has described a method for making green mango preserve at home. Tandon[9] has given an account of the manufacture of several preserves. Virendra Kumar[10] has given a method for papaya candy. Siddappa and Bhatia[11] have standardised a method for candying palmyrah palm kernel (*Borassus flabellifer*). Jain and Lal[12] have used cashew apple for making candy. Bhatia, Siddappa and Girdhari Lal[13] have standardised a conventional slow method as well as a vacuum-concentration method for making jack fruit candy. A method for apple preserve has been given by Jain, Bhatia and Girdhari Lal[14]. Girdhari Lal, Siddappa and Tandon[15] have written a chapter on preserves in their book on *Fruit and Vegetable Preservation.*

Preliminary Treatments

Preliminary treatments such as steeping in brine, citric acid solution, calcium chloride solution with and without the addition of SO_2, have been studied by Jain, Bhatia and Girdhari Lal[16] and Siddappa and Bhatia[1]. Recently, however, other factors such as variety, cold storage, freezing and thawing instead of pricking, etc., have been studied by Siddappa and Bhatia[18]. Green *Amari* apple has been found to be the best among the apples. Addition of SO_2 to the syrup is necessary to maintain the white translucent appearance in the finished preserve. Freezing and thawing in sugar syrup of 35° Brix can replace the laborious pricking process in the case of apples. *Amari* apple can be cold-stored for 3-4 months for making preserve. Brine-curing and pricking are essential in the case of *amlas*. They have also reported their findings on the absorption of sugar by the different portions of the fruit and their relation to the cell structure of the fruit. Girdhari Lal and Jain[19] have reported the usefulness of adding 0.05-0.10 per cent of citric acid to the syrup in the case of citrus peel and invert sugar in the case of carrot and ash-gourd. Siddappa and Mustafa[4] have stated that nearly 1¾ lb. sugar is required for candying 1 lb. of fruit and that any excess syrup could be profitably employed for the preparation of fruit syrups. Jain, Bhatia and Girdhari Lal[16]

have, however, reported that $1\frac{1}{4}$ lb. of sugar per lb. of prepared fruit will do. Siddappa and Bhatia[20] suggest the addition of about 1 per cent citric acid and 100 p.p.m. of sodium benzoate to the candying syrup in the early stages to prevent fermentation in the case of non-acid materials like jack fruit, carrot, etc. Subba Rao and Johar[21] have recommended the addition of 0.5 per cent acetic acid and 75 p.p.m. of sodium benzoate to the syrup.

Processing

Bhatia, Siddappa and Girdhari Lal[13] have compared the conventional and the vacuum concentration methods for the preparation of jack fruit preserve and candy and stated that the latter method is far superior to the first as regards colour and texture of the product. Sastry and Siddappa[22] have made a comparative study of the conventional, vacuum concentration and continuous high temperature methods for making *amla* preserve. The vacuum concentration method was found to be the best as regards retention of ascorbic acid, colour and texture. Siddappa and Sastry[23] have reported that *amla* juice which exudes during the pricking process in the factories can be a useful source of vitamin C (267 mg./100 ml.). Siddappa and Bhatia[23] have reported detailed analytical data regarding apple, *amla*, carrot and ashgourd preserves prepared by different methods, canned and stored for nearly two years. Sastry and Siddappa[24] have observed that in the case of carrot preserve by the conventional process, the retention of β-carotene is about 50 per cent and that the carrot preserve is still a rich source of β-carotene (4 mg/.100 g.).

Quality Control—Chemical and Microbiological

Bhatia and Siddappa[25] have determined the proximate, mineral and vitamin composition of the solid and liquid portions of preserves of apple, *amla*, ashgourd, carrot and *Coorg* oranges prepared in the laboratory under standard conditions (Table II).

The preserves are rich in sugar and calcium, but poor in ether extractives, protein, phosphorus, and iron. They are generally poor in their thiamine and ascorbic acid contents. Sastry, Siddappa and Girdhari Lal[26] have analysed a large number of commercial samples of canned preserves (Table III). There was no direct correlation between acidity and degree of inversion. The alcohol content and yeast count were generally low. *Amla* and myrobalan preserves had a high polyphenol content and *bael* and quince preserves, a comparatively low polyphenol content. Sodium benzoate was the preservative generally used.

Johar and Anand[27] reported that in the case of *amla* preserve, spoilage is due to osmophilic yeasts and this can be prevented by the addition of about 0.01 per cent sodium benzoate or sulphur dioxide. Subba Rao and Johar[28] have isolated from 29 commercial samples of preserves, 38 cultures which belong to three types, namely, S. *rouxii*, S. *mellis*, and S. *fermentati*. Subba Rao and Johar[21] have shown that a combination of 0.3 per cent acetic acid and 50 p.p.m. of sodium benzoate completely inhibits the growth of *S. rouxii* and S. *mellis*.

Therapeutic Values of Murrabbas

Preserves of *amla*, apple, *harar* and *bael* (*bilwa*) may partly owe their medicinal values to polyphenolic substances present in them. Although much data is available regarding the active principles present in these fresh fruits, very little of it is available in the case of preserves made from them (Dikshit and Dutt[29] Chakravarty and Das Gupta[30], Parikh, Ingle and Bhide[31], and Nadkarni[32]).

Systematic investigations in our laboratories, are in progress regarding the nature of carbohydrates, acids and polyphenols that are present in these fruits and the changes they undergo during processing and packaging. Siddappa[5] has reported that tannic acid only is present in *bael* preserve. In the case of *amla* and *harar* preserves, tannic and gallic acids are the two stable polyphenols, while others are destroyed to varying extents during processing. In the case of apple preserve, chlorogenic acid is present. There is very little of thiamine in the preserves as a result of fermentation by yeasts, (unpublished data). Steps have been taken recently to study the

TABLE II. *Proximate, mineral and vitamin composition of some Indian preserves*

Details of Analysis		Apple Preserve		Amla Preserve		Ashgourd Preserve		Carrot Preserve		Coorg Orange Preserve	
		Period of storage at 24-30°C (weeks)									
		40		13		6		6		3	
		Fruit	Syrup	Fruit	Syrup	Fruit	Syrup	Fruit	Syrup	Fruit	Syrup
1. Total soluble solids at 20°C %	...	...	67.48	...	70.48	...	62.40	...	66.48	...	60.40
2. Moisture %	...	27.88	27.58	25.43	24.75	33.92	32.18	29.61	26.33	32.44	33.75
3. Ash %	...	0.25	0.29	1.72	1.73	0.24	0.17	0.47	0.34	0.60	0.24
4. Ether extract %	...	0.12	0.04	0.03	0.30	0.02	0.01	0.01	0.01	0.03	0.01
5. Protein (N × 6.25) %	...	0.09	0.02	0.88	0.76	0.37	0.09	0.61	0.50	1.11	0.31
6. Total titratable acidity (as anhydrous citric acid) %	...	0.13	0.13	1.29	0.60	0.25	0.28	0.29	0.28	1.15	0.59
7. Crude fibre %	...	0.64	0.17	2.28	0.36	0.80	0.17	1.42	0.34	3.28	0.21
8. Reducing sugars (as invert sugar) %	...	32.62	32.51	59.06	62.75	43.23	39.11	28.43	28.28	29.29	36.86
9. Total sugar (as invert sugar) %	...	64.00	65.52	59.37	63.80	62.07	58.30	62.61	65.72	50.67	57.60
10. Degree of inversion %	...	50.97	49.63	99.47	98.35	69.65	67.08	45.40	43.02	57.80	63.98
11. Carbohydrates other than sugar % (by difference)	...	6.89	6.25	9.00	7.97	2.33	8.80	4.98	6.40	10.72	7.29
12. Calcium (mg.) %	...	130.80	53.08	72.11	29.18	69.82	50.67	73.53	63.74	114.40	47.09
13. Phosphorus (mg.) %	...	6.14	4.74	4.72	2.75	0.40	0.69	2.66	3.16	23.21	3.31
14. Ferric iron (mg.) %	...	2.80	0.85	0.97	0.97	0.08	0.00	0.00	0.00	0.64	0.77
15. Ascorbic acid (mg.) %	...	...	...	12.20	38.00	...	...	...	...	0.00	0.00
16. Thiamine γ per 100 g.	...	...	nil	...	1.68	...	2.45	...	3.99	...	nil
17. Carotene μ/g. 100 g.	...	...	...	...	...	...	...	957.6	...	...	...

TABLE III. *Analysis of some commercial preserves**

Preserve	Number of samples analysed	Total soluble solids (20°C)	Acidity as anhydrous citric acid	Degree of inversion	Alcohol content	Yeast Count	Tannins (as tannic) acid	Preservative
		Per cent Min. Max. (Average)	Per cent Min. Max. (Average)	Per cent Min. Max. (Average)	mg./100g. Min. Max. (Average)	Million/ml Min. Max. (Average)	mg./100g. Min. Max. (Average)	ppm. Min. Max. (Average)
1 *Amla* ...	11	67.4 72.4 (70.2)	0.06 0.20 (0.11)	27.6 92.9 (68.4)	171.8 936.5 (357.0)	3.6 20.7 (11.9)	54 193.5 (530)	Nil
2 Apple ...	15	67.4 72.4 (69.8)	0.08 0.10 (0.12)	8.0 63.9 (19.5)	246.3 1522 (927.3)	9.4 64.2 (40.1)	...	00. 28.0† (SO_2)
3 *Bael* ...	3	68.4 72.4 (70.7)	0.13 0.24 (0.19)	4.0 55.2 (29.4)	1195 1733 (1454)	63.3 68.5 ...	94.5 118.2 (106.1)	Nil
4 Quince (*Bihi*)	2	71.4 72.4 (71.9)	0.15 0.15 (0.15)	28.6 31.1 (29.9)	265.7 324.5 (295.1)	34.8 — ...	64.3 — ...	197-245‡ (221) Sod. benzoate
5 Myrobalan ...	1	72.4 —	0.11 —	56.5 —	359.8 —	26.3 —	626.9 —	Nil
6 Carrot ...	5	69.4 71.4 (70.4)	0.03 0.15 (0.10)	3.4 44.3 (18.5)	220.6 1830 (997.8)	6.5 55.3 (37.5)	Nil	0.02-1286† Sod. benzoate
7 Ginger ...	2	65.4 65.4 (65.4)	0.07 0.07 (0.07)	4.5 4.5 (4.5)	610.3 832.6 (721.4)	15.7 17.1 (16.4)	...	408-516‡ (462) Sod. benzoate

* The average values are shown in brackets. † Only one of the samples contained the preservative.

‡ Two samples only were analysed.

therapeutic values of *amla* and carrot preserves in collaboration with the Central Drug Research Institute, Lucknow.

Packaging and Distribution

A detailed study of the packaging of *amla*, carrot, mango and ashgourd preserves has just been completed using cans, glass jars and glazed stoneware jars and different temperatures of storage (Sastry and Siddappa, 1959). In the case of *amla* preserves, canned and stored for nearly two years, Siddappa and Bhatia (1959, *loc. cit*) have reported a total loss of ascorbic acid in the case of the brine-cured fruit and a small retention only in the case of the non-cured fruit. There was complete inversion of sugar (97-100%) due to the high acidity (1.1-3.8%) and low pH (2.4). The degree of inversion was low when the titratable acidity was low and the pH higher than 4.0. In the case of the carrot preserve stored for 2 years at 25-30°C, the β-carotene content was high (3.6-4.9 mg. per 100 g.) the pH was 4.0-4.1, acidity 0.31-0.35% as citric acid and the degree of inversion 59-62%. Under similar conditions of storage, in the case of ashgourd preserves the acidity was 0.23-0.30% as citric acid, pH 3.4-3.5, and the degree of inversion 74-91%. The canned carrot and ashgourd preserves were in good condition at the end of two years' storage at temperature of 25-30°C. More analytical data regarding microbial spoilage, etc., has recently been collected by Sastry and Siddappa[33]. There is much scope for following the changes in the minor constituents during the storage of the preserves.

Scope of Future Work

Although the vacuum concentration method of preparing preserves gives a product of superior quality, it can not be readily adopted by the Indian Murrabba (preserve) industry on account of the high cost of equipment. It is, therefore, necessary to make a further critical study of the continuous high temperature process to avoid intermediate fermentation. Although such a procedure has been found useful in the case of candied fruit[34] a considerable amount of modification in the equipment and processing conditions is necessary before it could be recommended for general adoption by the manufactures. Preliminary work in this direction has recently been started. Among the analytical investigations, work on the less known and minor constituents of the preserves, flavour factors, polyphenols, and other physiologically active factors, etc., requires urgent attention. When more systematic data on these aspects become available, it will be possible to make these excellent *murrabbas* better known in many other parts of the world.

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CHUTNEYS

By G. S. Siddappa and A. M. Nanjunda Swamy
(*Central Food Technological Research Institute, Mysore*)

Present Status of the Industry

Among the indigenous preserved fruit and vegetable products of India, mango chutney occupies a prominent place. It is also well-known in the West. The word *Chutney* is in very common usage and is known in the Indian household to mean a variety of pastes and sauces made from various ingredients which differ from place to place. The commercial product can, however, be broadly defined as a fruit cooked in sugar syrup with salt, spices and vinegar to a thick consistency. The chutney-manufacturing firms, some of which date back to the middle of the 19th century, are centred round Calcutta, Bombay, Madras and Bangalore. According to a report published in 1958 by the Ministry of Food and Agriculture, out of a total of 800 licensed fruit and vegetable preservation factories in India, 32 manufactured chutneys. The average annual production of chutney during the period 1952-56 was 734 tons valued at Rs 13.6 lakhs. Nearly 80 per cent of it was exported.

Method of Manufacture

The typical method employed for preparing mango chutney is generally adopted with slight modifications for the preparation of chutneys from other fruits also. The method consists essentially of two steps, namely, (*i*) Pickling of mango slices in brine and (*ii*) Preparation of the chutney.

(*i*) *Pickling:* There are two distinct methods which can be designated as the East and West coast methods.

(*a*) First Method : Fully developed raw mangoes are peeled, sliced, and the stones removed. The slices are smeared with about 5 per cent common salt and placed in barrels. Next day, the brine that is formed as a result of osmosis, is let out and more salt added. The process of letting out the brine and adding more salt is repeated for 4-5 days until the salt content of the slices reaches 15-20 per cent. The slices are then packed tightly in the barrels, with the addition of more salt sometimes.

(*b*) Second Method : The slices are smeared with about 8 per cent salt and placed in the barrels for 4-5 days, using weighted wooden boards to keep the slices submerged in the resulting brine. During this period, the entire surface of the brine is covered with a film of aerobic yeast. At this stage, the brine is withdrawn and the slices packed tight in fresh barrels, adding a further quantity of salt.

(*ii*) *Preparation of Chutney:* The brined slices are generally stored for 4-6 months. They are removed from the barrels, washed in water, pressed and then roasted in acetic acid or vinegar with ginger, garlic, chillies and other spices according to individual recipes. The slices are removed into a wooden vat. The sugar to be added is generally divided into three portions

and each portion added to the vat in the form of a thick syrup of about 75° Brix on successive days. This gradual addition of sugar avoids any shrivelling of the slices. Sometimes the finished chutney is boiled. After cooling, it is packed in glass jars or wooden casks for shipment. Sometimes, cured green papaya chunks, raisins and other dried fruits are added to the chutney.

Quality Control

Proper curing in brine is necessary to prevent disintegration of the slices during subsequent processing. At present, the brining of the slices is concentrated in a few localities in Bombay and Bengal and there is considerable scope for the technical control of the process and improvement of the sanitary conditions. The raw materials used should be of good quality. The mangoes selected should be of known variety and uniform maturity. The salt should be tolerably clean and free from excessive impurities. Sugar, spices, vinegar, etc., should be free from impurities and microbial contamination.

Varieties of Chutneys

There are six important kinds of mango chutney and they are: (*i*) sweet chutney, (*ii*) hot chutney containing more chillies, (*iii*) Major Grey chutney with a little more of garlic, (*iv*) Colonel Skinners chutney, with added raisins and rings of chillies, (*v*) Kashmir chutney, with the mango in the form of pulp instead of slices and (*vi*) Bengal club chutney, with the mango in the form of cubes and with mustard powder added.

In the case of chutneys from other fruits like apple, apricot, peach, plum, pear, tomato, water-melon rind, etc., the fresh rather than the brine-cured fruit is used. Methods for the preparation of these have been standardised in India.

Specifications for Chutney

Indian: According to the Fruit Products Order, 1955, and the Food Adulteration Act, a fruit chutney may be made from any suitable variety of fruit. The final product should have a minimum of 40 per cent of fruit and 50 per cent total soluble solids (w/w). The mould count should not exceed 40 per cent of the fields examined. Addition of 250 p.p.m. of benzoic acid is permitted. The manufacturers have not so far met with any serious difficulty in conforming to these standards except for an occasional high mould count.

United Kingdom: U.K. importers of mango chutney, however, have certain stringent specifications as regards colour, texture, freedom from insect and foreign matter, granulation of sugar and flavour. The acidity in the syrup should be at least 1 per cent and not more than 1.3 per cent w/w calculated as acetic acid. The total sugar as invert sugar should be 50-55 per cent. There should not be any added artificial colour or preservative. The copper content should not exceed 50 p.p.m. A considerable amount of systematic analytical data has to be collected to see to ascertain the extent to which the Indian products conform to these standards. A special investigation on this subject has recently been undertaken in our laboratories.

Research Work done on Chutneys

Most of the earlier work done in India on chutneys is of the nature of development of suitable recipes using fruits like apple, mango, apricot, plum, etc. Lal Singh and Girdhari Lal[2] standardised a recipe for mango chutney. Siddappa and Mustafa[3] have worked out a recipe for apricot chutney from white as well as yellow varieties. They have also indicated the possibility of preparing water melon rind chutney by similar methods. Tandon[4, 5] has given a number of recipes for making fruit chutneys. Jain and Girdhari Lal[6] have utilized cashewapple for making chutney. Bhatia, Siddappa and Girdhari Lal[7] have standardised a recipe for making sweet spiced jack fruit chutney. Recently, Girdhari Lal, Siddappa and Tandon[8] have included in their book on fruit and vegetable preservation a number of typical recipes together with methods of preparation for a large number of chutneys.

The brining of mango slices has recently been studied critically. Johar and Anand[9] have reported that the number of bacteria as well as of yeast was maximum in the case of 10 per cent brine and there was no yeast in the case of 20 per cent brine and dry salting. The slices were crisp

TABLE I. *Composition of mango chutney*

Sample	Refractometer solids %	Total sugars %	Acidity as anhydrous citric acid %	Volatile acidity as acetic acid %	pH %	Total ash %	Alkalinity of ash (ml. of N. acid per 100 ml. sample) %	NaCl %	Nitrogen %	Crude fibre %	Bacteria ($\times 10^6$ per ml.) %	Yeast and spores per 1/60 c.mm. %
Sweet chutney ...	71.1	67.7	1.02	3.31	2.8	1.63	3.51	1.05	0.043	0.90	103	90
,, ...	59.5	55.4	1.56	0.80	2.8	2.49	1.48	2.33	0.049	0.72	90	88
,, ...	60.1	57.1	1.42	0.63	2.7	2.83	0.61	2.66	0.036	0.97	85	82
,, ...	64.4	60.2	1.63	0.43	2.6	2.27	0.20	2.10	0.041	0.57	108	71
Hot chutney ...	67.8	65.6	0.87	0.30	2.9	1.73	1	1.20	...	...	...	...
Major Grey's chutney	67.6	64.5	1.02	0.20	2.6	1.87	...	1.42	...	...	...	...
Col. Skinners chutney	64.5	62.1	1.65	0.31	2.2	4.65	...	3.83	0.064	0.50	98	87
Bengal club chutney ...	64.0	62.0	1.62	0.32	2.2	4.59	...	3.80	...	...	...	...

N.B. (*a*) Chemical preservatives: None. (*b*) Artificial colours: Nil.
(*c*) Mould count: Percentage of positive fields much less than the limit of 40.

in 15 per cent brine. Addition of 1-3 per cent sugar to the brine did not help materially in the build-up of acidity beyond 0.5 per cent. Anand and Johar[10] have shown that green mangoes can be stored at 40-43°F and 85-90 per cent R.H. for about 40 days without affecting the quality of the chutney made from them. At 32-35°F, there is physiological break-down and above 47°F there is fungal growth. The same authors[11] have reported that the addition of 200 p.p.m. of SO_2 to 10 per cent brine, which is used for steeping the slices for about 20 hours and then repacking in barrels in fresh 5 per cent salt solution containing 200 p.p.m. SO_2 is highly useful in improving the colour and texture of the slices. These slices could be used directly without any washing for the preparation of mango chutney. Roy and Bose[12] have reported that the detection and estimation of added papaya in mango chutney is easy when it is present in the form of slices. In the crushed form, however, its estimation by chemical methods is rather difficult. The total nitrogen contents of mango and papaya are almost the same. The starch content is significantly different but the addition of starch-bearing spices and starchy materials to the chutney makes it rather an unreliable index for the estimation of the extent of adulteration.

Recently, Sripathy[13] has determined the chemical composition of Indian mango chutney by analysing 61 commercial samples to evolve suitable standards for quality control work. A few of the typical data are given in Table I.

Future Scope of Work

Of the several problems that require attention regarding chutneys, technical as well as scientific, a more detailed analysis of the various types of important chutneys with particular reference to less-known constituents and flavour factors, and control of the brining process and packaging of the products require immediate attention. Preliminary work on these aspects has already been initiated in our laboratories.

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PICKLES

By G. S. Siddappa and M. S. Subba Rao

(*Central Food Technological Research Institute, Mysore*)

Present Status of Industry

Pickles constitute an important section among the indigenous preserved fruit and vegetable products in India. In different parts of the country, a variety of pickles are prepared from different fruits and vegetables in almost all homes and consumed as good appetizers. Further, there are some factories also which manufacture different kinds of pickles for distribution and sale in the country as well as outside. According to the Agricultural Marketing Adviser to the Government of India, in 1957, the total quantity of pickles exported to other countries was 714 tons valued at Rs 10 lakhs. This export constitutes nearly 41 per cent of the total exports of all kinds of preserved fruit and vegetable products. The commercial production of pickles in the country forms 5-6 per cent of the total production of all categories of preserved fruits and vegetables. This, however, represents only a small fraction of the total quantity of pickles, prepared and consumed in many a home all over the country. The total value of pickles produced in the country is thus enormous. There is much scope for stepping-up the production of various types of typical Indian pickles and finding wider markets, as more and more reliable data is gathered regarding their nutritive and therapeutic values.

The firms manufacturing pickles are concentrated in areas like Madras, Bombay, Calcutta and Bangalore. Generally, two important types of pickles are manufactured in the country and they are:

1. Oil pickle.
2. Vinegar pickle.

The method adopted in the homes is slightly different in different parts of the country from the commercial practice. In the case of oil pickle, the finished pickle is covered with an edible oil like mustard oil, rape seed oil, sesame oil, etc. Some pickles are made in lime juice. In the case of vinegar pickles, which are typical of pickles manufactured in the West, vinegar is employed as a covering liquid for the finished product.

The word 'pickling' itself means preservation of food in common salt or vinegar and hence the terminology 'pickle' for fruits and vegetables preserved in this manner.

Methods of Preparation of Pickles

The three important constituents involved in pickling are salt, vinegar and lactic acid. Vegetables do not generally ferment, when they are covered with a strong brine or packed with a large amount of salt. When the salt concentration is about 15-20 per cent, even mould and lactic acid bacteria do not grow. It is, therefore, necessary to raise the concentration of salt

gradually so that sufficient lactic acid is produced by fermentation in the early stages to prevent any spoilage by other undesirable organisms. When sufficient lactic acid is formed, the lactic acid bacteria die out and any further change in the composition of the material is prevented. Although, at this stage, the pickle is ready for use, precautions are to be taken to prevent any spoilage by aerobic micro-organisms. This is achieved by preventing the access air to the pickle; otherwise, 'pickle scum' will be formed and this, by destroying the lactic acid, would bring about undesirable putrefactive changes in the pickle. This forms the basis of the practice of covering the pickle with oil or vinegar. Further, vinegar itself acts as a preservative on account of the acetic acid which itself is poisonous to many of the micro-organisms.

Pickling Process

The process of preparation of pickle consists of two main stages: (1) curing or fermentation of raw material either by (*a*) dry salting or (*b*) fermentation in brine or (*c*) salting without fermentation and (2) finishing and packing of pickle.

(*a*) *Fermentation with Dry Salting:* The vegetable is first washed in water and drained. It is placed in a keg or crock and a small quantity of salt take out from the weighed amount is sprinkled over it. Generally, 3 lb. of salt are taken for every 1000 lb. of the vegetable. Then another layer of vegetable is placed and sprinkled with salt. This process of adding vegetable and salt in alternate layers is repeated till the container is 3/4 full. A clean piece of heavy wooden board is placed on top of vegetable to keep it pressed so that the brine that is formed will submerge the vegetable in about a day. The container is placed in a warm place so that the fermentation can proceed. It is usually complete in 8-10 days under favourable conditions. A temperature of 27-32°C is most ideal. In cold weather, however, the fermentation may take 2-4 weeks for completion. When the fermentation is complete, the product is preserved by excluding air in one of three ways, namely: (1) by layering the pickle with an edible oil or (2) by filling the cask completely to exclude all air from the cask taking necessary precautions to obtain an effective seal or (3) by pouring molten wax over the brine to form an even layer. Each of these methods has its own advantages and disadvantages.

(*b*) *Fermentation in Brine:* This method is generally employed in the case of vegetables like cucumber, which do not contain sufficient juice to form brine with the salt added. It is customary to place the vegetable in 10 per cent salt solution to start with and then gradually increase it by adding more salt to a final strength of 15 per cent, allowing lactic fermentation to proceed in the meanwhile. The properly cured vegetable should be semi-transluscent and should be firm and crisp in texture. For proper storage all air should be excluded from the container.

(*c*) *Salting without Fermentation:* In this method the vegetables are packed with as much as 25 per cent of salt to prevent fermentation altogether. In the case of high acid materials like mango and lime, which are commonly used for pickling in Indian homes, this method of salting without fermentation is widely practised. The organic acids originally present in these materials appear to counter-balance any deficiency of lactic acid, which is not produced as fermentation is prevented by the high salt concentration. The subsequent addition of spices and oil is only to impart piquancy to the pickle and also to prevent spoilage during storage.

Finishing and Packing of Pickles

Vinegar Pickle: The cured vegetable is drained from the cask and excess salt is removed from it by soaking in cold or warm water. After removing the salt, it is stored for several weeks in plain vinegar of about 10 per cent strength. The object of this is to prevent the tendency of the vegetable to shrivel when subsequently packed in sweetened or spiced vinegar. It is then removed from the soaking vinegar and finally packed firmly into bottles and jars and covered with fresh vinegar. The bottles and jars are then sealed air-tight and stored. Among the vinegar pickles, pickled onion is the most important followed by walnut, beet root, cabbage, chilli and mixed pickle.

Other Pickles: Among the Indian pickles, other than the vinegar pickles, mango pickle

ranks first, then come cauliflower and turnip pickles followed by pickles of lime, chillies, dela, bamboo shoot, etc. They are classified according to their method of preparation. Generally the raw material is not cured in brine. Varying amounts of salt and spices are mixed with the prepared material and kept in stoneware jars. These are covered with cloth and kept in a warm place for 4-8 days with occasional mixing-up of the contents. Edible oil is added to form the so-called oil pickle. Methods and recipes from mango and other pickles like cauliflower pickle, turnip pickle, lime pickle, etc., are given by Lal, Siddappa and Tandon in their book[8]. These pickles generally contain an appreciable quantity of spices like cinnamon, caraway, mustard, clove, cardamom, ginger, turmeric and also onion and garlic.

Quality of Pickle

The quality of pickle is determined to a large extent by the quality of raw material used and also by the control exercised during the various processes.

Raw Materials: The salt should not contain impurities and added chemicals like calcium or magnesium phosphate or lime. The vinegar used should be generally either malt or cider vinegar. Sometimes, acetic acid may be used. Contact with iron equipment should be avoided as it leads to blackening in the pickle. The sugar and spices should be of extra pure quality and free from microbial contamination. The water used should be of potable quality and free from iron and excessive hardness. As regards equipment, copper vessels should not be employed as they are attacked by the acids in the pickle. Clean wooden casks and stoneware jars are best-suited for pickling.

Finished Product: The Fruit Products Order 1955, has laid down specification for (1) pickle in vinegar (2) pickle in citrus juice or brine and (3) oil pickle. In the case of vinegar pickle, the minimum percentage of acidity in the fluid portion should not be less than 2 per cent. In the case of pickles in citrus juice or brine, the salt content should not be less than 12 per cent and the citric acid content not less than 3 per cent. In the case of oil pickle, any edible vegetable oil may be used. The other general characteristics in the case of all these pickles as regards the absence of harmful chemicals, colours, preservatives, etc., are almost similar to those in the case of other preserved fruit and vegetable products.

Packaging and Sales

At present, 4 gallon tins are generally employed for packing and wholesale distribution of pickles. The practice of packing pickles in open-top sanitary cans for retail distribution has not yet come into vogue. This aspect of the problem requires careful investigation. Some preliminary work in this direction has already been taken up in our Laboratories.

Previous Work

Most of the work done on pickles in the country so far has been invariably limited to evolving of recipes for the preparation of a few of the more important pickles. It is only recently, however, that some work has been attempted with particular reference to the preliminary process of brining with a view to improving the quality of the raw stock for the preparation of vinegar pickle as well as chutneys.

Tandon[15-17] has collected a number of recipes for the preparation of a variety of pickles. Anand and Johar[2] have summarised information regarding the fermentation process employed in pickling. Recipes together with details of method of preparation of a variety of vinegar as well as oil pickles have been included in their book by Girdhari Lal, Siddappa and Tandon.[8] Hardayal Singh[9] has described a method of preparing lime pickle in South India. Roy and Singh[13] have suggested a recipe for mango pickle. Suryaprakasha Rao[14] has suggested the use of unripe, wind-fallen or seedling mangoes for making pickles. Iyer and Bhat[10] have studied the trends of growth and tolerance of spore-forming bacteria in salt and sugar. Anand and Johar[3] have studied the brining conditions for a variety of Indian fruits and vegetables like mango, raw papaya, *amla*, karonda, bitter gourd, onion, etc. A 10 per cent salt solution with the addition of 0.3-0.5 per cent acetic acid and

about 0.5 per cent turmeric powder in some cases only, preserved the material in sound condition. In the case of mango slices kept in 5 per cent brine, addition of acetic acid was more effective than that of citric, lactic or tartaric acids. They[5,6] have further reported that in 16 per cent salt medium, 0.36 per cent acetic is as effective as 16 per cent citric acid and 5 per cent lactic acid. As regards the effect of condiments on the growth of *A. niger* in mango pulp containing 15 per cent added salt, the same authors[4] report that most of the spices except cinnamon and clove, have little or no inhibitory effect on this mould. Common salt, although not effective by itself, supplements the preservative effect of cinnamon and clove. Whereas 0.3 per cent cinnamon was sufficient in the presence of salt, nearly 3 per cent was necessary when there was no salt. Anand, Soumithri and Johar[7] have shown that in mango pickle in 16 per cent salt, 25 p.p.m. of SO_2, 50 p.p.m. sorbic acid and sodium benzoate and 100 p.p.m., of propionate are equally effective in preventing fungal spoilage. When the salt concentration is only 8 per cent and below, much higher concentration of these chemicals are required. Anand and Johar[1] have reported that the number of bacteria as well as yeast was maximum in the case of mango slices in 10 per cent brine. There were, however, no yeasts in the case of 20 per cent brine or dry-salting. While the slices remained crisp in 15 per cent brine, they were either soft or mashy in other cases. Addition of 1-3 per cent of sugar to the brine did not materially help in the build-up of the acidity. The same authors[6] have reported that preliminary steeping of the slices in 10 per cent brine containing 200 p.p.m. of SO_2 for about a day and then draining and repacking them in 5 per cent brine with 200 p.p.m SO_2 improve the quality of the slices as regards their colour and texture.

Mazumdar, Muthu and Pingale[12] have reported that, in the case of mango pickle, two species of *Drosophila* generally attack it and this can be prevented by the application of materials like mustard oil, camphor, asafoetida, clove oil, etc., to the lid of the container. Clove oil, however, gave the best result.

Jain and Lal[11] have studied the possibility of packing pickles in cans avoiding subsequent bulging of the can due to fermentation.

There is very little data regarding the proximate, mineral and vitamin composition of important Indian pickles. A systematic investigation is necessary in this direction.

Future Work

Among the several important items of work that require attention, mention may be made of the need to make a thorough study of the effect of variety of mango on the quality of the pickle and any possible effect of factors like phenolic substances, tannins, etc. naturally present in some of the varieties, especially those that are commonly employed for pickling. A study of the nutritive and therapeutic values of some of the well known Indian pickles is also necessary.

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DEHYDRATION OF FRUITS AND VEGETABLES

By B. S. Bhatia, G. V. Krishnamurthy, S. Kuppuswamy and Girdhari Lal
(*Central Food Technological Research Institute, Mysore.*)

Preservation of foods by drying is perhaps the oldest method known. The special advantages of dehydrated foods are their concentrated form, cheapness of production and convenience in packaging and transport. The dehydration industry got an impetus during World War II in different parts of the world and even during post-war years, has retained its place in meeting the needs of the civilian market. In India also great deal of interest has been shown by various research workers in this field. The object of this paper is to review briefly the work done in this country on dehydration of fruits and vegetables.

1. Fruits

A method has been standardised for the preparation of banana figs[1]. The prepared fruit after dipping in 1 per cent Na_2CO_3 solution for 15 minutes, is rinsed with 0.05 per cent citric acid and washed in water. It is then spread on wooden flat-bottom trays, sulphured for one hour in the fumes of SO_2 obtained by burning sulphur at the rate of 8 lbs./ton fruit/1000 c. ft. space and dried at 55-60°C for about 20 hours. Tender green mangoes which have been found to be rich in ascorbic acid (about 350 mg/100 g. of fresh fruit) have been successfully dried[2] in the form of slices after steeping in dilute sulphite solution. The dried material retains at the end of 6 and 12 months of storage at 24-30° C nearly 77 and 45 per cent of the ascorbic acid respectively. The powdered material, however, loses its ascorbic acid fairly rapidly. Suitable method of drying grapes grown in Baluchistan has been reported[3]. A preliminary dip of 10-15 seconds in 2 per cent boiling lye solution is quite satisfactory for uniformly checking the grape prior to sun-drying. The dipped and sun-dried product known as *abjosh* has an excellent amber colour and pleasing taste. A high quality bleached *abjosh* has also been prepared from the *Haitha* grapes. Cost of production has been worked on the basis of large scale drying trials. South Indian white grapes have not been found to be quite suitable for drying[4]. *Amla* (*Phyllanthus emblica*) is reported to have been dehydrated satisfactorily at 140-145°F after blanching in 2 per cent NaCl for 7 minutes[5]. Sun-dried and dehydrated *amla* powders are reported to have vitamin C content of 10-14 and 24-28 mg./g respectively[6]. Vitamin C is stable for 3 months at 2°C. The losses at 18-23°C were 20-25 per cent. It was not found possible to prepare stable powders rich in vitamin C from guava, cashewapple, papaya and pineapple[6]. Jack fruit (*Artocarpus integrifolia*) bulbs sulphured at the rate of 16 lbs. of sulphur/ton fruit/1000 c. ft. space, have been found to give good quality dehydrated product[7] having a drying ratio of 3:1. Varietal trials on the dehydration of 10 varieties of Indian apples using cross flow hot-air drier have been made and data on drying rates, tray loading, sulphuring, dehydration and organoleptic quality reported[8]. Method has been standardised for the reprocessing of commercially dried fruits of inferior quality[9]. After washing for 5 minutes in running cold water and draining, the dried fruits are sulphured at the rate of 16 lbs./3 hours for apricots, 16 lbs./2 hours for figs, 8 lbs./4 hours for black currants, 8 lbs./1 hour for green raisins and 4 lbs./1 hour for red raisins, burning sulphur for one ton of fruit in 1000 c.ft. space in each case. Dehydration is carried on at 150-155° F (65.5-68.3° C) for 3-4 hours.

2. Vegetables

Considerable amount of data were collected on drying of vegetables during war days. The work was carried out at Lyallpur at the instance of Supply Department of Government of India with the object of developing vegetable dehydration industry in the country on sound scientific lines. Singh and Lal have reported a detailed method of drying potatoes and brief outlines of the methods of drying of some of the important vegetables like onions, cauliflower, carrots and peas using a home drier[10] and recirculating air blast type experimental tunnel dehydrator[11]. Methods of dehydration of 16 commonly grown vegetables—bitter-gourd, brinjals, cabbage, carrots, cauliflower, knol-khol, fenugreek (*Methi*), okra, onions, potatoes, pumpkin, radish, spinach, squash, tomatoes and turnips, have been standardised and

data collected on tray load, drying time and temperature, drying ratio and cost of production for each, using an experimental recirculating air-blast type tunnel dehydrator[5]. Loss of vitamin C during dehydration is reported[6] in case of cabbage (88 per cent), potato (49 per cent), cauliflower (72 per cent), carrot (50 per cent), turnip (93 per cent) parsnip (79 per cent), knol-khol (83 per cent), onion (88 per cent), brinjals (85 per cent), bitter-gourd (72 per cent) and okra (13 per cent). Effects of processing conditions on vitamin C retention is discussed. Interesting observations on the rate of dehydration of root vegetables in heated air have been made by Bhatia *et al*[12]. A four-stage counter-flow hot air drying system with inter stage heating which has been developed for the dehydration of vegetables in strip or shred form is compared with a less complex system of fewer stages for drying strips of scalded carrot or potato. Satisfactory drying is possible in some cases in 6-7 hours even in a single stage system, though not necessarily with good thermal efficiency. The possibility of bacterial hazards associated with low initial drying temperature is discussed. It has been reported that the protective action of potato starch against the oxidative changes in dehydrated carrots is due to the branched chain component, amylopectin, and not to the straight chain component, amylose[13]. However, improvement due to starch coating has not been considered sufficient to suggest it as an alternative to packing in inert gas. Dried green jack fruit of good quality which can be reconstituted and used as a cooked vegetable, has been prepared after steeping in 0.1 per cent potassium metabisulphite solution for 30 minutes[14]. Method of preparing dried tender bamboo shoots has been reported[15]. Two orange flesh American varieties of sweet potatoes have been dried and the dried product found suitable for making *Halwa*[16].

3. Fruit Juice Powders

A patented method has been developed for the preparation of fruit juice powders[17]. The changes taking place in the ascorbic acid content during processing of juice from three varieties of Indian oranges, namely, Coorg and Nagpur oranges (loose skinned mandarin type) and Sathgudi orange (*Citrus sinensis*), a tight skinned type, have been studied and a method for the preparation of orange juice powder has been standardised[18]. There is loss of 31-57 per cent ascorbic acid during the preparation of orange juice powder employing a vacuum shelf drier; the loss is 100 per cent when an ordinary shelf-drier is employed. The orange juice powders compare favourably with similar imported products. They can be fortified with ascorbic acid and other additives, and can be used in the preparation of sweetened orange juice, squash and blended fruit juice beverages. Supplementary value of orange juice powder to poor rice diet has been studied[19]. Physico-chemical changes during vacuum concentration and dehydration of passion fruit juice (*Passiflora edulis*) have been reported[20]. Losses of ascorbic acid and carotene during vacuum drying of passion fruit juice ranged from 5.1-10.4 per cent and 2.5-4.7 per cent, the overall losses during vacuum concentration and dehydration of the two vitamins being of the order of 11.1-20.5 and 5.1-9.0 per cent respectively. Changes in ascorbic acid and carotene during freeze drying and spectral reflectance curves of fresh and freeze dried passion fruit juice have been reported[21]. Jack fruit powder[22] and cocoanut powder[23] of good quality have been prepared by the patented process. Indian gooseberry or *amla* (*Phyllanthus emblica*) with 20-25 per cent added common salt has been successfully spray-dried in the form of a powder which had a vitamin C content of 8.6 mg./g. of salt[24]. A good quality date tree juice has been prepared by drum drying at a pH of 7.2. Composition of fresh and dried products is given and compared with open pan dried juice and market sample[25].

4. Dried Fruit Pulp

Siddappa and Bhatia have patented an improved method for the manufacture of fruit pulps in the form of sheets and slabs[26]. The method[22] consists in adding to the fruit pulp a sweetening agent, heating the pulp, sieving it and then cutting the dried pulp into slabs which can be wrapped in cellophane paper and packed in card-board boxes or glass jars. Changes in the carotene and ascorbic acid contents during drying of six south Indian varieties of mango pulp have been report-

ed[27]. There was a heavy loss of 92-98 per cent of reduced ascorbic acid and 30-40 per cent loss of carotene. Loss of carotene in the dried product during a storage period of 12 months at 25-30° C was of the order of 30-49 per cent. Most of the storage loss of carotene occurred during the first three months. Method of drying *Fazli* mango pulp using a double drum drier has been worked out[28]. The light golden yellow coloured product has negligible vitamin C, 8.33 p.p.m., carotene and 34.9 per cent reducing sugars on moisture free basis (moisture 3.5 per cent). Pulp of *Raival* variety of mangoes has been dried in shallow pans (1/8″ thick) initially at a temperature of 50° C for 4-6 hours in a shelf-drier followed by drying for 1 hour at 60° C in a vacuum drier[29]. Addition of 10 per cent sugar and sulphitation improves the quality of dried product. Ripe papaya pulp can be dehydrated satisfactorily at 55-60° C using 1 cm. thick layer after adding 5-7.5 per cent sugar, 0.05 per cent citric acid and 0.3 per cent potassium metabisulphite[30]. The dried product keeps well for about 8 months at 24-30° C, although there are considerable losses in nutrients, *viz.*, ascorbic acid 100 per cent and β-carotene 47 per cent. Drying of *Bael* (*Aegle marmelos correa*), pulp with 350 p.p.m. added SO_2 and 30 per cent sugar, in a shelf-drier at 120° F for 15 hours gives a good quality product with regard to taste, flavour, colour and grinding properties[31]. The powder fortified with vitamin C at 66 mg./100g. remained stable for 3 months. Recipe for the preparation of jack *papad* (spiced *papad*) using pulp from pale coloured jack fruit bulbs which are neither fully mature nor completely raw, has been described[32].

5. Fruited Cereals and Strained Baby Foods

The preparation of fruited cereal products like flour, vermicelli, flakes and crisps from fruits like mango and papaya have been reported[33, 34]. The products are highly palatable and possess good keeping quality. They have also been found to be good sources of carotene. Further improvements in the preparation of mango cereal flakes using atmospheric drum drier instead of vacuum drum drier and using raw wheat flour instead of cooked flour have been made[35]. Recipes for the preparation of tomato, guava, banana and pineapple cereal flakes have been developed[36]. Good quality strained baby foods from mango (Mangotine), banana (Banatine), peas, beans, carrots, beet and squash have been prepared by roller drying technique[37, 38]. The recipes and proximate, mineral and vitamin composition of Mangotine (baby food prepared from strained mango pulp) and Banatine (baby food prepared from strained banana pulp) have been reported.

6. Tuber Flours

Method of preparation of flour from sundried and dehydrated sweet potatoes has been reported[39, 40]. Proximate composition of flour and its use in the preparation of *chapaties*, bread, milk pudding (*Firni*), biscuits and cakes have been described. Method has been standardised for drying of *arvi* (*Colocasia*) and preparation of its flour[41] which is rich in carbohydrates and has been found suitable for making *chapaties* when mixed upto 25 per cent with wheat flour.

Methods of preparation of tapioca flour[42, 43] and tapioca soji[43] have been described. Tapioca flour can be utilized for the preparation of *chapaties*, *poories* and vermicelli after partial gelatinization of the flour with boiling water prior to kneading which imparts certain desirable physical properties to the dough almost similar to those of wheat flour[43]. Preparation and uses of jack seed flour have been reported[44, 32].

7. Soup Powders

The process of making pre-cooked vegetable soup powder, has been evolved using a combination of ingredients such as tomato, potato, peas, starch, onions, sugar, salt, spices and hydrogenated fat employing cabinet or drum drier for dehydration[45, 46]. Soup powder keeps well for a year under ordinary conditions of storage. Compounded soup powders from potato, carrot, mushrooms, peas, beans and tomatoes have been prepared using a cross-flow dehydrator and their storage behaviour studied[47]. Proximate and mineral composition of these soup powders have also been determined and compared with those of foreign brands.

8. Miscellaneous

A new process for the manufacture of garlic powder has been developed which apart from reducing the labour charges during dehydration to about one-fortieth, yields a powder of better pharmaceutical value (antibacterial activity), colour and flavour[48]. Some technological aspects of manufacture, packaging, and storage of this powder have been reported[49, 50, 51]. Based on sorption isotherms (E. R. H. curve), the packaging characteristics of garlic powder[52], onion powder[53], ginger powder[54], soup powders[47], fruited cereal flakes[36], dehydrated apples[8] and walnuts[55] have been reported.

Some processing and storage aspects of dehydration of field beans, lima beans and peas by deep fat frying method have been studied[56]. Possibilities of using dried fruits for the manufacture of high quality wines, fruit brandies and industrial alcohol have been indicated[57]. Analytical data on wines prepared from dried plums, pears, raisins, black currant and apricot have been reported. Some technological aspects of dehydration of apples[58] and storage of dehydrated potatoes[59] have been reviewed.

Conclusions

A large amount of work has been done on various aspects of dehydration of fruits and vegetables in India. Some of the products like fruit juice powders, fruited cereal flakes, strained baby foods, dried fruit pulps and soup powders appear to be very promising and it is hoped that industrial development of these products will follow soon. Some industrialists are already showing keen interest in a few of the processes mentioned above.

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DEHYDRATION OF ANIMAL FOODS

By S. Kuppuswamy, K. Gopinathan Nair, B. S. Bhatia and N. L. Lahiry

(Central Food Technological Research Institute, Mysore)

The dehydration of foods of animal origin has received considerably less attention in India than that of fruits and vegetables. The second world war gave some fillip to the dehydration of meat, but not (unlike in other countries) to that of milk, fish or eggs. With a view to ensuring regular supplies to the armed forces, the Government of India put up, during the war, a number of meat dehydration factories, all of which, however, closed down after the cessation of hostilities due to the lack of civilian market for dehydrated meat. Dehydration of milk and milk products is definitely a post-war development so far as India is concerned, but the industry shows promise of sizable expansion in the near future. Sun drying ('beach drying') of fish has been an age-old practice in the coastal areas (especially in Bengal and Kerala), but the production of dried fish did not register any appreciable increase during the war years. Artificial dehydration of fish, like the production of dried egg products, has still to make a beginning in this country.

Meat

Before the second world war, beef and buffalo flesh ('biltong') used to be dehydrated in Uttar Pradesh and Delhi for export to Burma (roughly 536 cwts. per annum), but this trade has since ceased, mainly due to the strong feelings against the slaughter of cattle[1]. In some places, particularly Assam, however small quantities of goat's meat are sun dried for local use[1].

Details of the method of dehydration of meat in Government factories during the war have been described in the pamphlet 'Production of dehydrated meat in India' by Bartlett[2] (1943) and also in the report[1] on marketing of meat in India (1956) and in the publication 'Dehydrated meat[3]' of the D.S.I.R. Food Investigation Board (1953). While only two plants were in operation in 1943, eight factories, each with a capacity of one ton of the dehydrated product per day, came into production by 1944, giving a total annual output of 2000 tons. The raw material was mainly goat's meat, but small quantities of sheep's meat (mutton)

were also processed. Goat's meat was invariably dried in the form of raw slices, whereas sheep's meat was dried in the form of mince, thereby effecting considerable saving in the labour and time involved in slicing. The sliced, raw dehydrated meat, although inferior in general palatability to the precooked minced product, was preferred by the Indian troops and the goat carcases available were particularly suited to the production of such a product in view of the almost complete absence of adipose tissue. Each of the one ton units was capable of dealing daily with approximately 900 goats of 50 lb. live weight. The animals were slaughtered either by the Mohammedan ('Halal') or Hindu ('Jhatka') method. In the absence of refrigeration facilities, the utmost care was taken, particularly during the hot and rainy seasons, to see that there was the least possible time lag between slaughter and dehydration. Proper pre-slaughter care of the animals facilitated the flaying and dressing operations and the production of meat of high quality. The kidneys were dehydrated separately for use in the rations of British soldiers. The deboned meat was trimmed of excess fat and cut into slices, 2″-7″ in length, 1″-2½″ in width and 1/6″ to 1/8″ in thickness, brined in 10 per cent salt solution for 2-3 minutes, spread out on expanded aluminium trays at the rate of 1 lb. per sq. foot and dried in an overdraught counter current tunnel dehydrater. The conditions of dehydration were as follows: temperature and relative humidity of inlet air, 145-155°F and 15-20 per cent; temperature and relative humidity of outlet air, 123-140°F and 45 per cent; and velocity of air flow, 600-750 linear feet per minute. The time of dehydration varied from 6-10 hours, depending on the relative humidity of the atmosphere; in general, relative humidities in excess of 60 per cent were not conducive to proper drying of the material. The dehydrated meat was immediately packed into clean kerosine type tins of 4 gallons or 1 gallon capacity at the rate of 11 lbs. and 3 lbs. respectively. The containers had a small brogue hold in the lid, which were sealed with a spot of solder after sterilizing the contents for 3 hours at 150-160° F. The entire process, right from slaughtering of the animal down to the packing of the dehydrated eat took nearly 22 hours. The specifications for the dehydrated meat required that its moisture content should not exceed 10 per cent and its fat content 15 per cent. The product required to be soaked for 2 hours in water and then cooked in boiling water for 2 hours before it was sufficiently tender for eating. The yield from 100 lbs. live weight was 35-40 lbs. of whole meat, 19-20 lbs. of sliced meat and 4.5—5 lbs. of dried meat. The cost of production inclusive of packaging worked out to about Rs 6-7 per lb. of the finished product.

The results of a series of experiments on the dehydration of meat carried out at the military dehydration factory at Patna have been described in a series of three publications by Sen Gupta[4-6]. The first paper[4] embodies the results of investigations on the relative percentages of the 'breakdown products' from meat (*i.e.*, dressed carcasses, bones, fatty pieces, lean meat, dehydrated meat etc.) and the effect of certain processing operations on the quality and composition of the dehydrated product. The relative quantities of the 'breakdown products' were found to be dependant on the breed, age and sex of the goats. Thickness of meat slices in excess of 3/8″ adversely affected the drying rate, as did brining, which, in addition, brought about a small loss of the meat proteins. Sorting out the fatty pieces from the dehydrated meat prior to packaging brought down the moisture and the fat contents and was thus a desirable step in the production of dehydrated meat of proper quality. Final sterilization at 160° F for 3 hours also brought down the moisture content by 0.2—1.5 per cent. The second publication[5] relates to the determination of the times necessary to dehydrate the meat slices under different humidity conditions of the atmosphere. The drying times for different ranges of humidities were obtained by trial and were plotted against the corresponding relative humidities to give the 'drying time line'. In the rainy season, when the relative humidity was very high, the moisture contents of many samples after dehydration exceeded the prescribed limit of 10 per cent, in spite of prolonged drying times; it was, however, possible to remove the extra moisture by heating in the dry heating chamber. The third paper in the series[6] relates to the effect of dehydration on the nutritive value of goat's meat and edible offals like heart, liver, lungs, kidney and brain. De-

hydration brought about small to moderate losses in different nutrients like protein, calcium, phosphorus, total and ionisable iron, nicotinic acid and vitamin C. The destruction of vitamin B_1, however, was complete in contrast to the loss of only 60-65 per cent reported by British workers[3]. A possible explanation for this difference is that in the Indian method of dehydration, the meat was sliced, dipped in salt solution and then dehydrated for 7½-10 hours in the sliced form, whereas in the British method, the meat was pre-cooked, minced and dehydrated for only 4-5 hours.

Work has recently been started at the Central Food Technological Research Institute on the standardization of the method of preparation of dehydrated soup powders based on both mutton and chicken[7]. Storage studies with these products are in progress.

Milk

The application of the process of spray-drying to the dairy industry, with particular reference to the production of dried whole milk powder, skim milk powder, whey powder, cheese powder, ice cream powder and other sundry milk products have been discussed at some length[8], as also some engineering aspects[9] of spray-drying and the changes taking place during the drying of milk[9]. The need for proper quality control in the production of dried milk and dried milk products has been emphasised[10]. Three molds and eighteen aerobic bacteria have been shown to occur in dried milk prepared in the laboratory in addition to the anaerobe, *Clostridium perfringens*, an organism of faecal origin; the three isolates of molds were identical with the species of *Aspergillus*, *Penicillium* and *Glibotrys* encountered previously among the flora of ghee[11]. The need for and the prospects and possibilities of the production of dried milk and dried milk products in India have been dealt with in detail by Roy[12-14]. The production of dried milk at least in limited quantities is deemed desirable especially to meet the demands of the armed forces[12]. Various steps involved in the production of both roller-dried and spray-dried milk powder have been described[13]. The equipment needed for the production of dried milk products and the scope for their fabrication in India have been outlined[13] and cost estimates have been given in respect of a factory producing spray-dried whole milk powder at the rate of two tons per day[14].

Owing to the restrictions on imports during the second world war, an attempt was made for the commercial production of milk powder by the National Nutriments, Ltd., Calcutta[13]. The attempt was, however, short-lived as the company failed to compete with the imported products in respect of both quality and price[13]. Commercial production of dried milk was revived in 1955 following the gift of a spray-drying plant by the UNICEF to the Kaira District Co-operative Milk Producers' Union[15]. This plant, located at Anand in Bombay State, with a capacity for producing 5 tons of dried milk per day, is at present being used in the processing of skim milk powder, whole milk powder as well as half-cream milk powder. A roller-drier with ½ ton capacity per day belonging to Messrs Healthway Ltd.,[16] Varanasi, in Uttar Pradesh, is employed in the production of whole milk powder, skim milk powder as well as different types of milk foods. Four more projects have been sanctioned by the Government of India for the production of dried milk foods[19], including the one sponsored by Messrs Glaxo Products, Ltd., at Aligarh in Uttar Pradesh[18].

A large amount of work has been done by Chandrasekhara and co-workers at the Central Food Technological Research Institute, Mysore, on the preparation of dried milk foods of diverse types suitable for feeding infants. Dried milk foods intended for use as partial or complete substitutes for human milk have been reviewed[19] and the prospects of their production in India have been discussed[20]. The early attempts[21, 22] were directed towards the production of malted milk powder ('Horlicks-like product') and malted milk powder flavoured with cocoa ('Ovaltine-like product'). These products were found to possess a satisfactory shelf-life and consumer appeal[21] and the patent[22] covering their production has already been taken up by the industry for commercial exploitation. Attention was later diverted to making the process of infant food production cheaper, easier and applicable to wider areas by substituting cane sugar for malt and buffalo's milk

for cow's milk. As raw material for the preparation of infant foods, buffalo's milk, apart from its readier availability,[20, 23] is also economically the sounder proposition because the large amounts of butter fat obtained as the bye-product[19] would help bring down the production costs considerably. The chief disadvantage of buffalo's milk is its high curd tension as compared to cow's milk or the well known milk foods available in the market. It has, however, been shown that the curd tension of buffalo's milk can be brought down to the desired level by boiling and addition of salts such as citrates and phosphates[24]. Optimal conditions for the preparation of infant foods from buffalo's milk were standardized using both the spray-drying[25] and the roller-drying[26] methods. The essential steps[25] in the former method are: (1) pasteurization, (2) reduction of fat content of the milk to 2.5 per cent and addition of cane sugar in sufficient quantities so as to adjust the protein content of the final product to 22-24 per cent and its fat content to 14-16 per cent, (3) addition of buffer salts, (4) concentration, (5) addition of vitamins to the concentrated milk, (6) homogenization, (7) spray-drying and (8) packing in containers under nitrogen. The roller-drying process is essentially similar except for the fact that the steps of concentration and packing under nitrogen are unnecessary[26]. In addition, the use of the roller-drier has been found to possess the following advantages[26]: (*a*) relatively low initial cost of equipment, (*b*) space-saving compactness and (*c*) suitability to regions of moderate milk production (10-20 thousand pounds per day). The fact that the roller-dried milk products are, as a rule, far less soluble in cold water as compared to the spray-dried milk products is not considered a serious drawback in so far as infant foods are concerned which are invariably reconstituted in hot water in Indian homes[28]. A large-scale trial of the spray-drying process involving the production of 3 tons of infant food was put through at Anand with funds provided by the National Research Development Corporation[27, 28], while a smaller trial involving ½ ton of the product was carried out at the factory of Messrs Healthway Ltd., Varanasi, using their roller-drying equipment[26]. When packed under similar conditions, the shelf-life of the roller-dried products has been found to be far superior to that of the spray-dried products[29, 30]. Infant feeding studies carried out at different centres showed that infant foods prepared according to either process cause no digestive upsets and promote normal growth[31-33]. The ex-factory cost for the production of 3 tons of spray-dried[17] infant food or ½ ton of roller-dried[16] infant food per day has been estimated to be Rs 2.07 per pound.

Fish

Little work has been carried out in India on the processing of fish using modern methods of dehydration under controlled conditions. Venkataraman and co-workers[34] have investigated the utility of infra-red heating in drying salted fish. At a temperature of 45°C. the fish is reported to be dried to a moisture content of 40 per cent in 6 hours and 99.95 per cent of the bacteria originally present destroyed during the process. By raising the temperature to 60°C, it is possible to obtain a hard-dried product below 10 per cent moisture content. The chief factor limiting the widespread application of this process for commercial drying of fish would be the high initial capital expenditure. Working at the Massachusetts Institute of Technology, Proctor and Lahiry[35] have shown that dehydration has no effect on the amino acid composition of the proteins of shad (*Alosa sapidissima*) and haddock (*Melanogrammus aeglefinus*).

50-70 per cent of the total catch of marine fish in India is reported to be cured[36], mainly by sun-drying[37, 38] with or without the application of salt. Sun-dried fish is cheaper than fresh fish[39] and, as such, forms an important item in the dietary of the low income groups in Bombay[39], Bihar[40] and Bengal[41]. In Bengal alone, more than 40,000 tons of sun-dried ('satki') fish are reported to be produced annually[41]. The practices followed in various parts of the country in drying different species of fish have been described[36-38, 42, 43]. They are invariably primitive and unhygienic and provide scope for improvement in different directions[44]. The dried fish has high moisture and insoluble ash contents (the latter through admixture with sand and dirt) and its keeping quality is rarely satisfactory[41, 44]. The moisture

content of salted dried fish should not exceed 25 per cent in order that it may keep for a sufficiently long period without spoilage[45].

The estimated annual production of prawns in India is of the order of 150,000 tons[46]. There used to be a big volume of trade in dried prawns which were being exported to Burma, but the import restrictions in that country have affected the trade seriously[46]. Prawns are plentiful only during certain months of the year and are relatively scarce during others. Hence the need for its preservation arises[47, 48]. The commonest method of preservation is sun-drying[47, 48], the prawns being spread over the sand without even being washed or cleaned[47]. Since the glut season coincides with the outbreak of the monsoon, atmospheric conditions are usually quite unfavourable for drying, with the result that a large proportion of the dried prawns is fit to be used only as manure[47]. Investigations carried out at the Central Food Technological Research Institute have shown that by the incorporation of a small quantity of fungicides like sodium propionate and sorbic acid, the dried prawns keep better with much lower microbial count[46]. The Fisheries Department of Madras State has developed a method of preparing 'semi-dried prawns'[47, 48]. The process essentially consists in blanching the prawns in 6 per cent brine for 2-6 minutes, shelling, treating the shelled meat with cold saturated brine for 15 minutes and drying in an electric oven at 50°C. till the material assumes the appearance of fine pink-coloured lozenges (approximately 45 per cent moisture content)[47, 48]. On the field scale, the drying is done on raised bamboo barbacues by solar heat; 6 hours drying is usually sufficient on a sunny day[47]. Semi-drying has practically no effect on the amino acid composition of prawn proteins[47]. During the process of semi-drying, the bacterial count of fresh prawns is reduced by 98 per cent by blanching alone; brining effects a further reduction[48]. Normally semi-dried prawns keep well for a period of two months[47, 48]. Ascorbic acid has no beneficial effect on its shelf life[49].

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APPLICATION OF MICROBIOLOGY IN FOOD PROCESSING

By Dyal Singh Johar and T. N. Ramachandra Rao

(Central Food Technological Research Institute, Mysore)

Introduction

Foods such as fruits, vegetables, meat and fish are highly perishable under ordinary conditions and have to be processed to make them safe for human consumption. The quality of the product is determined largely by the quality of the raw materials and the control during their processing into the final product.

Some of the vegetables are grown in effluent waters obtained from sewage farms which bring heavy microbial load in the raw material. Similarly the fish, whether of marine or fresh water origin, carries a microflora which under favourable conditions, can act as potential carriers of food-poisoning organisms. The unhygienic conditions of our slaughter houses have a deleterious effect on the keeping quality of meat products over long periods. The climatic conditions of a subtropical country like ours will certainly produce more heat-resistant organisms.

Since our raw materials carry heavy microbial load, apart from physical and chemical tests, it is essential to have efficient microbiological control also. Processing is a means of sterilizing the product with a view to inactivating any potent infection which is either of spoilage group of organisms or of pathogenic nature. Processing time has to be determined bearing in mind the resistance of organisms found in it. Therefore a study of the microbial load at various stages of washing and blanching has to be made. Post processing studies relate to leaker spoilage, inadequate processing and cooling water contamination. Though standard processes for the safe canning of a large number of food products are readily available, yet non-acid foods require further systematic study under Indian conditions. Microbiological tests are necessary for the control of quality in different kinds of processed foods.

The handling, storage and manufacture of any food product for human consumption demand the proper appreciation and application of the principles of sanitation. Many types of product contamination must be recognised and steps taken to avoid them. The programme of canning-plant sanitation is directed towards the prevention

of contamination by bacteria, yeasts and moulds. Certain types of organisms can easily be determined to have come from the raw material. Hence there is need for strict control over the hygienic conditions of the factory and the workers to guard against out-break of any disease caused by harmful micro-organisms.

Lastly, destruction of the pathogenic and spoilage bacteria being the primary object of processing, a knowledge of the type of bacteria being associated with the foodstuff is essential for the proper control of the process. Apart from being agents of food spoilage, the micro-organisms can also play a useful role in food processing. They help to process many raw materials by growth and fermentation, thus bringing into being new food products. Some of the more important aspects and products of food microbiology will be dealt in the following pages.

Beverages

Beverages, both alcoholic and non-alcoholic, have been in use in the country from fairly early times. The onset of summer conditions gives a fillip to the non-alcoholic beverages for a period of 3 to 6 months in the year. These beverages include fruit juices, herbal extracts as well as aerated waters. Work done at the Central Food Technological Research Institute, Mysore has established two new drinks *viz.*, 'Ginger Cocktail' and 'Pan Supari Nectar'. The former is being manufactured by a commercial firm under the trade name 'Gingerella'. The general aspect of the preparation of unfermented beverages has been detailed by Tandon[1], Rai[2] and Suri[3]. Work on the preservation of 'Neera' has been carried out by Subrahmanyan and Johar.[4] Studies by Ramachandra Rao and Johar[5] on the fortification of beverages with autolysed yeast to enhance their nutritional levels have shown encouraging results.

The manufacture and sale of aerated waters is on a footing by itself. Aerated water means a clear, carbonated and flavoured drink. Unfortunately in a product such as an aerated soft drink, especially in summer temperatures, organisms begin to grow. The acidity is less favourable to bacteria, with the possible exception of the lactic bacteria, but favourable to yeasts and moulds. The two main sources of infection are water and the bottle. Water must comply with minimum standards *i.e.*, a microbial load not exceeding 100/ml. and total absence of colon bacilli. Sugar is a dangerous raw-material from the bacteriological point of view[5a] and even colour additives may bring in heavy contamination.

Bottle washing is an important step in the soft drink manufacture. Yeast is the first enemy of quality and it grows best in weak sugar solutions. A clean bottle is one which should pass a laboratory test for sterility. Hence regular examination of washed bottles for bacterial tests is necessary.

India is importing alcoholic beverages to the tune of 1.5 crores of rupees to meet her civil, military and pharmaceutical needs. With abundant resources of fruits in the country in areas such as Assam, U.P. and Coorg, it is possible to meet our entire demand locally. Keeping this object in view, methods have been standardised for the preparation of wines from grapes, mango, cashew apple, bananas, wood-apple and orange. Siddappa *et al.*[6] have worked on the preservation and processing of South Indian white grapes. Analytical data and the cost of production of alcoholic beverages from fruit juices have been worked out by Johar and Anand[7,8]. A recipe for 'tonic wine' based on local fruits and herbal extracts has been standardised and the product is now on the market.

Fermented and Processed Foods

The action of micro-organisms on organic matter results in a number of products and by a judicious selection of substrate and microbe, many useful food products can be obtained.

As part of the project for preparation of predigested protein-rich foods, soya bean cake was inoculated with moulds having proteolytic and diastatic activity. By suitable processing, several protein-rich products have been standardised and given for commercial exploitation.

For the production of 'Aminol', a predigested protein-rich powder from soya bean, a patent application has been filed in the name of B. S. Lulla *et al.*[9] Similarly a protein-rich pasty product called 'Bovite' has been prepared and application filed for issue of patent in the name of Subrahmanyan, V. *et al.*[10] Besides the above

two, a liquid having the same properties as 'Soya sauce' has also been standardised.

Subrahmanyan *et al.*[11] have described in detail a method for the production of vegetable milk from groundnuts. Studying the changes in the nitrogenous constituents of groundnut milk during lactic souring at 37°C, Moorjani and Bhatia[12] have reported that the total nitrogen content remained unchanged while non-protein nitrogen and ammonia nitrogen increased as a result of souring. Conditions for the production of dehydrated vegetable curd powder have been worked out[13]. Curd or buttermilk (lactic souring of milk), is a common dietary constituent of the people of India. In a series of papers, Balakrishnan[14, 15, 16] and Baliga *et al.*[17] have shown that curd provides more favourable conditions for bacterial synthesis of vitamin B_1 in the intestinal tracts of rat and improves the growth of the experimental animals. They further record that the total count of bacteria as well as the number of coliform organisms are highest in the group of rats fed curd. Diana B. Coelho and Bhat[18] have recently shown that fermentation of groundnut helps to destroy the trypsin inhibitor and also improve the absorption of its proteins. Yet another fermented product developed by Anand[19] is the preparation and preservation of fermented carrot juice 'Kanji'. A process for the production of enriched and concentrated vegetable protein food in the form of a hard-type of cheese, from groundnut has been developed and is being standardised by Subrahmanyan *et al.*[20]

Vinegar

As a condiment, vinegar has been in use for a long time and is produced by the successive alcoholic and acetic fermentations of sugars from different sources which characterise the vinegar as fruit vinegar, malt vinegar and sugar vinegar. Home making of vinegar has been described in an article by Gupta[21] and a general treatment of other aspects of vinegar manufacture by Tandon[22]. In a detailed report on the 'Quality of vinegar', Natarajan *et al.*[23] have attempted a preliminary evaluation of the quality of some of the vinegars produced in our country and noted their common defects. Based on the results which indicated high values for vinegar from *gur* and cane juice, a small scale home vinegar generator has been developed, which can be easily set up from Indian material and which can use the plentiful supply of cane juice available in our villages. Details of the process and the approximate cost are outlined in a paper titled 'Home Vinegar Generator'[24].

Mention may be made of the production of *Jaman* vinegar which the author[25] claims to be cheaper than grape or cider vinegar and is easy to make. The analysis of the final product with a total acidity of 5.33 per cent as acetic acid is achieved.

Spoilage of Processed Food Products

Microbial infection in processed foods is not only a cause of concern to the health of the consumer but also an economic loss to the canner. Fruits due to their high acidity and sugar content are susceptible to mould and yeast attack while vegetables and meat products, which are non-acidic have largely bacterial infection.

Iyer and Bhat[26, 27, 28] have studied the thermal resistance and tolerance to preservatives of spore forming bacilli encountered in nature and which are of significance in food industries. Sugar is the first material of importance to canning industry. That this raw material can carry contamination has been studied by Johar[5a], and Shukla and Prabhu.[29]

Jain *et al.*[30] have standardised a method for the canning of vegetables such as potatoes, tomatoes, cauliflower and peas in curried form. Yet, numerous reports of spoilage in canned peas and cauliflower have appeared. Dutta and Bose[31, 32] have determined the average bacterial load in vegetables at different stages of canning and also studied the spoilage of canned peas by *B. polymixa* group of organisms. More recently, Sripathy *et al.*[58] have isolated a heat resistant strain of *B. licheniformis* from canned peas and studied its physiological characteristics.

Pickles and preserves have formed a part of the Indian diet from ancient times. Commercial exploitation of this art on a scientific basis has only recently made a beginning in our country. Large scale manufacture has brought in its wake, problems of microbial spoilage.

In a series of papers, Anand and Johar have

studied various aspects of the problem such as fermented and unfermented pickles[34], effect of condiment[35], action of organic acids[36] and microbiology of brining[38].

Johar and Anand have studied the nature and prevention of spoilage in *amla* preserve while Subba Rao and Johar[39, 40] have isolated the spoilage organisms from *murrabbas* and reported on the inhibitory effect of acetic acid and sodium benzoate, singly and also in combination. Madhu, Raghunath and Bhat[41] have isolated the bacteria and studied the microbiology of indigenous pickles and preserves.

Fish

A survey of the bacterial flora of sea water is necessary with a view to understanding the biochemical role of these micro-organisms in fish spoilage. In a study of the sea water from the coast of Madras City, the author[41a] has laid emphasis on the seasonal variation, density of population and the presence of a group of marine bacteria of biochemical significance. Similar studies of sea water and marine mud of Mandapam[42] and the inshore sea water of Tellicherry coast[43] have been made. The significance of bacterial flora associated with fish lies in the fact that it must explain the pattern and probable extent of spoilage.

Ninety five strains of bacteria were isolated from the fresh water fish of Mettur reservoir[44]. A difference in the flora (bacterial) of the surface fishes and bottom fishes has been noted and its significance discussed.

The bacterial flora of marine fish of Tellicherry coast[45] has shown that micrococci form the largest group, accounting for nearly a third of the isolates. *E. coli* were not detected, while the presence of lactose fermenting *paracolobactrum*[46] was definitely established. The fresh 'Bombay Duck' *Bombil*[47] had a bacterial flora of its own, among which *Bacterium phosphorum* and *Sarcina littoralis* or their variants predominate. The fresh fish is also associated with *Escherichia* while in the dehydrated fish the micrococci predominate.

General aspects of canning of fish[48] and its preservation and nutritive value[49] have been studied. The effect of temperature on the growth of fish spoilage bacteria[50] and the biochemical change of fish muscle[51,52] and fish fillets[53] stored at different temperatures have been recorded. Work on the effect of aureomycin on the keeping quality of fresh water fish[54], and also its inhibitory effect on marine fish[55], and bacteria[56] has been done. Salt tolerance of the bacterial flora of fish[57], and salt cured marine fish[58] are recorded.

Riboflavin (By Microbial Fermentation)

Riboflavin is synthesised by some microorganisms but very few species of fungi, yeasts and bacteria have been found to produce the vitamin in sufficient amounts to warrant the production on an industrial scale employing them.

Work done in India, reveals that Subrahmaniam *et al.*[59] isolated a mutant strain of *Saccharomyces cerevisiae* BY_2, which contained in the wash 22 μg. of riboflavin per c.c. The influence of some environmental factors on this mutant were studied by Mitra[60, 61], who improved the riboflavin yield to 65.2 μg. per c.c. in a 7-day fermentation. Studies on the synthesis of riboflavin were done by Giri[62], who indicated that purines may mediate the synthesis in this organism. They also studied the role of amino acids in riboflavin synthesis.

The production of riboflavin by *Eremothecium ashbyii* using various brans and oil-cakes has been studied by Lulla[63]. A riboflavin concentrate containing 8-10 mg. of the vitamin per g. of the product has been prepared from wheat bran medium by the above process.

Citric Acid

Citric acid is produced by the fermentation of sugars by mould. The acid is widely used in preserved fruit industry, besides many other chemical and pharmaceutical industries. Citric acid is produced by many different strains of *Aspergillus niger*. The activity of individual strains frequently varies so much that the stabilization of a high acid producing capacity is regarded as one of the most difficult problems in dealing with the process.

Attempts to produce citric acid by mould fermentation in India started in 1940[64]. Successful

fermentation of molasses by strains of *A. niger* are recorded by Nirmalapada Chatterjee[65]. Later on, by using a strain of *A. luchensis*, Bindal *et al.*[66] fermented cane sugar to yield citric acid.

Biochemical studies on the metabolism of *A. niger* using selected strains were worked out by Damodaran *et al.*[67] and pilot plant trials have been conducted. Lewis and Johar have studied the relationship of spore size[68], influence of iron[69] and the effect of methanol[70] on citric acid yield. Agave juice substrate[71] has also been used as a source of carbohydrate for production of citric acid. The general uses of citric acid, citrus oil[72], and its manufacture from sugar[73] have been indicated.

Enzymes (Diastase and Amylase)

There is an increasing demand in India for diastase and amylase for use in textile and pharmaceutical industries. These enzymes can be prepared by the action of micro-organisms on agricultural wastes and by-products such as various brans and oilcakes. Bindal and Sreenivasaiya[74] investigated the possibilities of utilizing various agricultural waste products for the growth of *Aspergillus oryzae*. Nutritional requirements of a diastase producing strain of *A. oryzae* were later studied by Raghavendra Rao and Sreenivasaiya[75]. Lulla *et al.*[76] have reported the production of fungal diastase from lucerne and wheat bran. They have also evolved a method for an active preparation of pharmaceutical diastase.

Amylase by the microbial method can be produced by bacteria, fungi and actinomycetes. Lulla and Subrahmanyan[77] have found that maximum enzyme production by *Bacillus subtilis* could be secured on a medium containing wheat bran and lucerne powder. Roy[78] prepared crystalline α-amylase from fungal sources and studied its amino acid make-up and other biochemical properties. Pant *et al.*[79] have reported encouraging yields of amylases from actinomycetes which compared favourably with the commercial brands of diastase.

Lulla and Johar[80, 81, 82] have developed methods for the production of amylase both by open and submerged fermentation methods. The same workers pointed out the utilization of spent wash for the production of fungal amylase.

Microbial Food Poisoning

The micro-organisms which exude poisonous toxins are generally associated with products like canned fish and meat products, and non-acid fruits and vegetables[83]. Efficient microbiological control over the hygienic conditions of the factory and the worker can eliminate the out-break of diseases caused by harmful micro-organisms. The idea of food-poisoning or 'botulinum' due to the consumption of non-acid foods containing toxins produced by organisms like the heat-resistant *Clostridium botulium* have largely become things of the past. It has been found that lowering of the pH and addition of tamarind[84], citric or tartaric acid[85], facilitate safe processing.

A potential source of food-poisoning micro-organisms is referred to by Bhat[47], because of the frequent occurrence of species of micrococus in the dehydrated form of the fish, '*Bombil*'. Two instances of food-poisoning in acid fruits have been investigated. In grapes[86], the presence of relatively acid-tolerant micro-organisms caused gastro-intestinal disturbances, while in water-melon[87,88] the juice was an excellent substrate for the growth of the organisms of the food poisoning group.

Conclusions

The brief survey given above is an attempt to indicate the major lines of work undertaken in India in the recent past in food microbiology. The authors had to restrict the review to a few selected topics only because of the comprehensive nature of the subject.

Food industries in India have come up only during the last decade and the consequential problems of microbiological spoilage have only recently caught our attention. But even this short review brings before us the large gap left to be covered in coming years. The future lines of work stretch before us, in the fields of microbial load of raw materials used, cannery plant sanitation, processing of non-acid foods like meat and vegetables, study of heat-resistant bacteria

encountered under Indian conditions and storage life of processed products under conditions of high temperature and high humidity prevalent in parts of coastal India. The food microbiologists have to face this challenge in the decade to come.

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PROBLEMS ASSOCIATED WITH THE PACKAGING AND TRANSPORTATION OF PERISHABLES

By N. V. R. Iyengar, B. Anandaswamy and H. B. N. Murthy
(Central Food Technological Research Institute, Mysore)

The world production of perishables has shown an increase since the world war II. The total quantity of fresh fruits and fruit products in international trade during 1956 was equivalent to about $10\frac{1}{2}$ million tons as against the average pre-war equivalent of $8\frac{1}{4}$ million tons[1]. This increase in the international trade is attributed to a general rise in the production of fruits in all parts of the world. A similar trend has also been observed in the production of marine products.

The increase in the production of perishables is also seen in India. Special attention is being paid through the Five Year Plans to increase the production to a sizable amount. The second five year plan provides for rejuvenation of the existing 500,000 acres of orchards and planting of new orchards to the extent of 200,000 acres[2]. There is also a significant increase in the production of marine fish from 570,860 tons in the year 1950 to 707,349 tons in the year 1956. This is expected to reach the target of 4,000,000 tons at the end of the second five year plan with the technical assistance of various agencies[2].

The increased production of perishables will have a significance only when the produce reaches the consumer in a good condition at a reasonable price. This could be achieved by preventing them from spoilage at the source, during transport and marketing. It is estimated that the spoilage of these perishables which is as high as 25-30 per cent in India, could be reduced by adopting improved packaging, handling and efficient system of transport. This aspect of the problem brings to the fore a number of other factors like harvesting, grading, pretreatment, suitable warehouse and marketing facilities etc. All these operations are interrelated and are of equal importance for providing the consumer with quality products. In this effort, the producer, the shipper, the carrier and the salesman have to work efficiently to realise this objective.

Adequate packaging and efficient system of transportation play a significant role in saving perishables and are directly linked with the economy of the country like ours which is mainly depending on agriculture.

Almost all parts of India produce a large variety of fruits and vegetables with certain specialities of the area. These areas generally have large volumes of production from where the trade to metropolitan cities originates. It is, therefore, obvious that the produce has to travel long distances before they reach the consuming market. It is in this process that products require careful handling so as to deliver quality produce to the consumer.

FRUITS AND VEGETABLES

Harvesting

Normally the fruits and vegetables are harvested when fully mature or just slightly over. Such a stage of harvest is good only for local markets but not for despatch to distant places. There is a need for standardising the 'maturity stage' for harvesting thus reducing the percentage of spoilage as well as the glut in the market. This system is followed in many countries particularly in the U.S.A.

Pretreatment

In western countries great progress has been made in the pretreatment of produces before packaging and despatch. Methods like washing, waxing, cooling, colouring and wrapping with and without treated papers, before shipment to the market, are in vogue. Work on waxing and wrapping done at this Institute has shown distinct advantages in prolonging the storage life of fruits and vegetables[4, 5, 6].

Grading

Under the present system of international trade of perishables, grading is obligatory in all the advanced countries and is being followed according to the purpose for which the produce is intended *viz.*, table use, local market, distant internal consuming centres, industrial or other uses. In India, since grading is not insisted upon, it is observed that smaller size and indifferent quality fruits are put together in the same package. Thus, the physiologically older fruits enhance the ripening and increase the chances of spoilage of the physiologically younger ones. The Agricultural Marketing Adviser has emphasised in several of the marketing reports the importance of grading and this is being followed in the trade particularly of oranges[7]. Similarly, the grading is adopted with regard to eggs[7]. Such a practice is to be adopted for all other perishables particularly fruits like mangoes, bananas, apples, pineapples, potatoes etc.

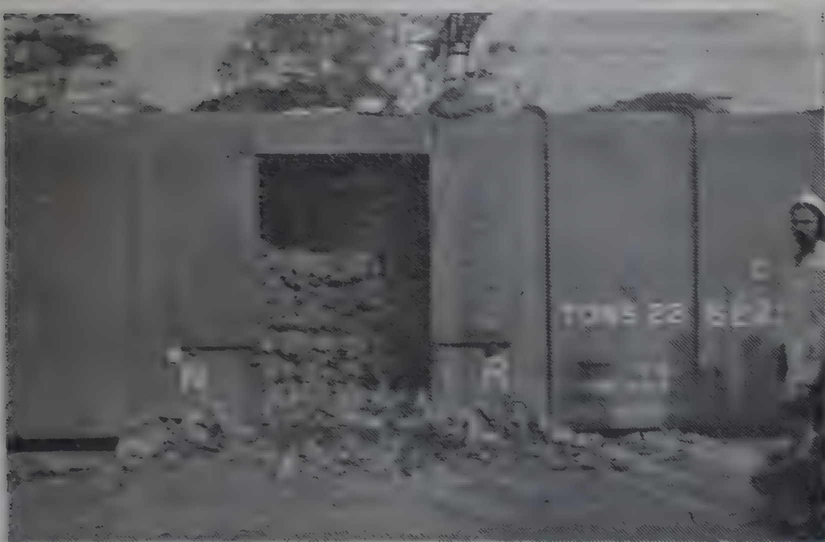
Packaging

The packages must be capable of (*a*) protecting the produce from the hazards of transport (*b*) preventing microbial and insect damage and (*c*) minimizing the physiological loss in weight. The present methods of packaging fruits and vegetables have been evolved out of considerations such as the local availability of materials which could be transformed into suitable containers and also the prevailing method of handling and transport.

With the increase in the demand for fresh fruits and vegetables in metropolitan cities which are growing in their size and population due to industrialisation, the volume of trade has gone up at a tremendous rate, necessitating the import from long distances. While the traders have met this demand by getting larger supply, they have not realised the need for changing the old pattern of the packaging practices to cope up with the increasing demand.

Fruits and vegetables are biologically living systems and undergo continuous physico-chemical changes during their life time. Even after harvest, they continue to respire, resulting in physiological loss in weight, together with the evolution of carbondioxide and volatile gases—ethylene being one of the important constituents. It has been established that ripening of fruits is accelerated in an atmosphere containing even small proportion of ethylene[8]. Such a condition is to be found in a package which is not adequately ventilated. This is particularly significant in the long distance transport in wagons or lorries with not enough ventilation.

Grapes in mud pot containers



A straight load of Banana in a railway wagon

A truck load of Banana leaving for markets in Bombay

Materials used for the containers depend on their availability and cost. The shape and size depend on the mode of transport, type of handling, distance and number of journeys to be made. The materials that are used for construction are generally, bamboo, wicker, wood, gunny, plastic films, fibre and corrugated boards etc. In western countries packages have been standardised for each commodity according to the purpose and the nature of the products to be packed. This system has materially helped the shipper and the carrier.

Bamboo and wicker baskets, and wooden crates of different shapes and sizes are used for a number of perishable commodities in India. Mud pots, gunny bags, palmyra mats are also used for a variety of purposes. As the dimensional stability and ability to withstand stacking load of the bamboo and wicker baskets are very low, they are suitable only for head load or for transportation in bullock carts which carry a small number of baskets at a time and that too over short distances.

Moreover, these packages are not strong enough to withstand the rough handling and they are not rigid enough to take the stacking load of more than two or three layers deep without the risk of the fruits in lower baskets being crushed. The wagon capacity thus cannot be utilised to the maximum extent, thereby resulting in higher level of freight rates. Packaging of grapes in mud pots is quite common in South India. It is often observed that during transport the mud pots break and the contents get damaged. Though the mud pot has its own advantages as a container for grapes and such other fruits, it ha to be handled very carefully thus impairing th speed of handling. Up country shippers, how ever, use wooden lug boxes with saw dust for th transport of grapes.

In some cases like mangoes and bananas straight load is practised in certain regions For example, bananas in bunches are loade without any packaging into the railway wagon and transported from Khandesh to Bombay Similarly, the Bangalora mangoes are transporte as such in straight loads from Madras State t Calcutta, Hyderabad and Bombay. In thes cases, it has been observed that losses due t spoilage are considerable.

Cushioning materials and fruit wraps

The cushioning materials used for packagin perishables are dry grass, paddy straw, leave

saw-dust, paper shavings etc. For the cushioning material to be useful, it should, in addition to having resilient property, have the ability to dissipate the heat of respiration of the produce. It should be free from infection which is likely to be passed on to the fruit and it should not injure the soft fruits in any way. It is important that the cushioning material itself should be physiologically inactive.

The use of fruit wraps is commonly in vogue in western countries. This practice is also finding favour in many parts of India. In one of our studies on this subject it was found that mangoes wrapped with diphenyl treated papers had a distinct advantage in reducing spoilage.

It is obvious that the containers used for the transport of perishables should be (*a*) sufficiently rigid to protect the contents (*b*) capable of being stacked to a tall pile (*c*) easy to handle and not too heavy (*d*) suitable for more than one commodity and (*e*) economical in usage.

Transport

In the U.S.A. the use of better packaging methods and refrigerated means of transport has materially resulted in the large scale development of the horticultural area of the South and West and without these improvements, the produce would never reach the distant markets in a usable condition[9].

The main carriers of perishables in India are the railways. In many places the commodities have to travel quite long distances before they reach the nearest railhead. Lorries are the main means of transport on road, and in hilly regions bullock carts and animals are used.

The losses and spoilage of perishables in road and railway transport are due to rough handling and unforeseen delays in delivery. It is necessary for the carriers to improve the handling procedure and it is equally important on the part of the shipper to improve his packages which can be handled easily and yet strong enough to withstand transport hazards.

In order to study the existing methods of packaging and transportation of some of the perishable commodities in our country, investigations were carried out on typical commodities like mangoes[13] and potatoes, which are transported over long distances to consuming centres[10-11]. The above studies have indicated that losses due to spoilage in road and rail systems of transport are mainly due to inadequate packaging and rough handling. The package currently in use in South India is the conical type bamboo basket in which mangoes (without any wrapping) are packed with paddy straw as the cushioning material. It was noticed that the mangoes were not graded before packaging. The package has not much dimensional stability and it is not also capable of withstanding stacking load. It was found that by using a rectangular type of bamboo basket in which the fruits could be arranged in two layers as against three layers in the conical basket, the spoilage of fruits due to crushing was reduced by about 25 per cent. This type of basket is dimensionally stable and is strong enough to take the stacking load usually met with in transport and warehouses. Wrapping of fruits in treated papers was found to be quite advantageous in checking microbial spoilage.

A similar experiment on potatoes has shown that spoilage of the tubers could be reduced by using gunny bags with a greater degree of ventilation than a closely woven one.

As regards the carrier system, while it is desirable to have refrigerated vans for the transport of perishables, the use of ventilated and insulated vans would considerably prolong the shelf life of the commodities and also reduce spoilage. In certain sections of the railways in India, wooden wagons with louvering are in use. As an immediate expedient it is necessary to use these types of wagons in preference to all metal wagons, since the build up of temperature and humidity in all metal wagons due to the respiration and transpiration of the perishables is very high resulting in heavy spoilage losses.

In any method the first essential for successful transport of perishables is proper loading in the vans, not only to prevent mechanical damage to the package *en route* but also to permit air circulation all round the container. According to D. F. Fisher much of the spoilage found in perishables is due to improper loading[12]. As regards handling hazards of packages, our studies revealed that packages receive a fairly large number of 3-5 feet drops leading to a great deal of

mechanical damage to the fruits. Further, commodities packed in gunny bags are usually lifted by means of books, resulting in a great degree of bruising and cutting of the tubers. It seems obvious that handling of packages during loading and unloading needs careful attention. In western countries all loading and unloading operations are done by means of fork lifts.

Prepackaging

Among the more recent developments in the marketing of fresh produce, prepackaging of fruits and vegetables has revolutionised the trade practices in U.S.A. and in some parts of Western Europe. More than 20 per cent of the total produce valued at about 11 billion dollars are prepackaged and sold through grocer's stores in the U.S.A[13]. In this method of marketing, the produce is first prepared by trimming off waste materials like leaves, stalk, stem, cull etc., washed cleaned and weighed quantities are put into suitable size containers made usually from transparent, cellulose or plastic films. The containors are generally provided with enough number oe vents for the exchange of gases. Our studies on prepackaging of betel leaves[14] (*Piper betel* Linn), sweet pepper (*Capsicum grossum* Sendt) and green chillies (*Capsicum ocuminotum* Fingh) at different temperature conditions and relative humidity have shown that the shelf life of these commodities could be extended for a considerable length of time, and in some cases the shelf life could be even doubled by packing them in polyethylene bags of suitable gauge with adequate vents[14,15].

FISH

As has been mentioned earlier, a great deal of attention is being paid to the development of fisheries in India. At present the fisheries are not fully exploited to the same extent as in America, Scandinavian countries, Europe and Japan. The fishermen in India generally use small sailing boats and take long time to return to the shore. The catch is heaped in open holds of the boat, where the fish remain exposed to sun and weather. Fish, being a very highly perishable commodity, there should be as little a time gap as possible between the time of catch and its storage in cold stores for further transportation to consuming centres.

The main forms of transport from landing centres to distributing areas are head-loads, bicycles, animals, motor vehicles, railways, bullock carts, boats and trucks. Recently insulated railway wagons have been introduced in some parts of the country for transport of fish. The containers generally used are nets, baskets, gunny bags, wooden cases etc., packed with ice and saw dust, and of late ice boxes are also becoming popular.

At present the movement of fresh fish from the coastal area is mostly confined to short distances from the coast to inland areas. There is a large volume of movement of fish on cycle. However, small quantities are transported by lorries and by rail.

In our recent study of the industry in west-coast particularly in Mangalore, it was noticed that per day 200-250 cyclists carry as much as 120 lbs. of fish each to inland markets. The distance covered by each carrier is about 35 miles.

Transportation of Fish to inland markets by cyclists

Although the fish was iced with about 20 lbs. of ice before despatch, it was found that no ice was left in the basket at the destination and the overall temperature of the fish was as high as 16°-18° C. The quality of the fish was far from satisfactory as indicated by tests performed on the spot.

It was observed that if the melting of ice could be delayed even for 3-4 hours, the fish would reach the present consuming markets in better conditions than at present. This would also enable the cyclists to take the fish into further inland consuming markets.

Experiments in our laboratory have shown that lining the existing fish basket with 300 gauge polyethylene film, laminated between two layers of gunny cloth, would retard the melting of ice by about 3-4 hours. This method does not involve change in the size, shape or the carrying capacity of the baskets. Further work is in progress in this direction. For long distant transport of fish, work is in progress for devising suitable containers. In order that the various efforts that are being made to improve the fishing industry in India should be effective, it is extremely important to develop suitable methods of packaging and efficient means of transport for this highly perishable commodity.

It may be seen from the foregoing that adequate packaging and efficient means of transport of perishable commodities are urgent needs of the country. Adequate packaging will not only result in saving a large volume of highly nutritious food from wastage but also reflect in greater returns to the producer, better food for the consumer and improved agricultural economy of our country.

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STORAGE AND PRESERVATION OF PERISHABLES

By H. C. SRIVASTAVA

(Central Food Technological Research Institute, Mysore)

India, at present, produces over ten million tons of fruits and vegetables and the production is constantly on the rise due to improved methods of cultivation and increasing acreage. It is estimated that about 30-40 per cent of the total produce goes to waste due to inadequate transportation facilities and lack of proper storage. This is because the commercial application of storage research on perishables is of recent origin in India. The first organised refrigerated storage work was started by I.C.A.R. at Kirkee in 1939 when a team of workers found out the optimum conditions and storage life of a few of the commercial fruits of India. More comprehensive work on different lines of storage and preservation has been started only recently at the Central Food Technological Research Institute, Mysore—one of the National Laboratories of India in 1950. Since then, considerable work of practical utility has been carried out in different lines of storage of perishables. As a result, the number of cold storages in the country has increased to 182 today (see table) as compared to 30-40 in 1948. Most of the cold storages, at present, depend for their technical advice on this Institute. The average capacity of a single cold store is only 660 tons. Most of the cold stores situated in the inland towns store potatoes, 62,000 tons of which are stored every year. It is estimated that a few commercial freezers now in operation in the country have a combined storage capacity of 300 tons, the main commodity frozen being fish. This refrigerated storage capacity is inadequate for the vast country like ours. This Institute is instrumental in the development of cold storages at various consuming centres. The earlier work done on the study of post-harvest physiology of various perishables has helped in extending researches on this problem in various directions. A review of the work so far done in this country is presented in this article under different sub-heads of storage and preservation of perishables. The results of these researches will not only enable to tide over the glut season, but will also help in successful transportation of perishables from growing centres to consuming centres in our country and in promoting of export to foreign countries.

TABLE. *Distribution of cold storage installations in the various states of India (Excluding the Defence Services' installations)*

State	Nos.
Andhra	2
Bihar	22
Bombay	20
Delhi	12
Jammu and Kashmir	1
Madhya Pradesh	12
Madras	9
Orissa	2
Punjab	15
Rajasthan	6
Uttar Pradesh	46
West Bengal	35
Total ...	182

Physiological Behaviour of Perishables

Ranjan and Khan[1] determined the sugar content, acid content and the CO_2 output in guava at different stages of growth and their results indicate a correlation between sugars and acids on the one hand and between acids and respiration on the other. Ghatak[2] made a chemical examination of the fruits of *Tribulus terrestris* Linn. and has shown the presence of starch hydrolysing enzyme, a peroxide, a glucoside and a phlobaphene. Pectic changes in potato tubers at different stages of growth have been studied by Dastur and Agnihotri[3]. Loss of insoluble protopectin and middle lamella pectin forms a favourable ground for the growth of spoilage organism. They have also studied the effects of temperature on the pectic changes in mature tubers under storage at room temperatures. Girdhari Lal[4] conducted chemical studies on the physiology of apples and evolved a method for measuring the chemical changes and the rate of respiration in the stored apples. He also attempted to study the rate and character of metabolic changes in the senescent phase by determining

the dry weight, different sugars, acids, total nitrogen and alcohol soluble residue.

Singh, Sheshagiri and Gupta[5] have studied the natural drift of metabolic changes in developing fruits (*Krishna bhog* and *Langra* mangoes and local guava). The respiratory index of the entire fruit exhibits two maxima. The respiration drift runs more or less parallel to the percentage of reducing sugars at all stages of development. In mango, the declining respiratory activity at later stages has been experimentally shown to be due to hindrances in the gaseous exchange through the hard stony endocarp and the fleshy mesocarp of the fruits. On the basis of the physiological and chemical changes, the life of the fruits under examination has been classified by the authors into four more or less well defined stages: (1) juvenile, extending between seven and twenty one days; (2) adolescent, extending between twenty one and forty nine days; (3) climacteric, extending between forty nine and seventy seven days and (4) senescent, extending from seventy seven days onwards.

The same authors[6] have studied the respiratory behaviour of mangoes and guavas under varying gaseous environments. An enhancement of carbon dioxide output is observed in transferring mangoes from cold storage at 8°C to 30°C. Mangoes kept in an atmosphere of nitrogen exhibit an increased carbon dioxide output and a change from nitrogen to an atmosphere of air also enhances the rate of carbon dioxide production. The value of glycolysis worked out on Blackman's assumption is found to be four times that of oxygen respiration, while three-fourths of the carbon taking part in glycolysis is possibly built back into the system. The carbon dioxide output is at a minimum in 9.2 per cent oxygen, and an increase or a decrease of this tends to increase the carbon dioxide production. An oxygen mixture of 9.2 per cent is the critical concentration below which there is probably a competition between aerobiosis and the respiratory quotient (R.Q.) at this critical point is 0.85, suggesting the possibility of a mixture of fats and carbohydrates forming the substrate for respiration.

Singh and Mathur[7], while working on the permeability of the periderm of potatoes to gases during storage, have shown that throughout the storage period, there is a continual decrease in the permeability of the periderm. Towards the end, however, due to sprouting there is an increase in the permeability. The internal CO_2 concentration progressively increases during storage and is accompanied by a depletion of oxygen in the interior gas. The progressive accumulation of CO_2 indicates that the rate of metabolism does not decrease in proportion to the lowering in the rate of superficial evolution of CO_2.

Singh and Mathur[8, 9], in their investigation on physiological and chemical changes during the development and ripening of potato tubers, have correlated the stage of maturity of the tubers with certain characters in the ontogeny of the vines.

The respiration of potato tubers during storage has been investigated in detail by Singh and Mathur[10]. They observed that adolescent, mature and ripe potatoes continue to be distinguished by thier respiratory behaviour throughout the period of storage. It was also noted that when potatoes are placed in storage there is a progressive increase in the concentration of internal CO_2 until the expiry of the period of dormancy, the percentage of this gas falling rapidly with the commencement of sprouting. It was observed that there is a negative correlation between R.Q. and the percentage of internal carbon dioxide during the stages of dormancy and sprouting. The data obtained during storage concerning the permeability of the periderm of the potato to gas indicate that the permeability of the superficial tissues decreases considerably during the dormancy of tubers. It was shown that tubers stored for 10-12 days at 18°C lose considerably less weight during subsequent storage than those stored at 70°C. This emphasises the importance of pre-storing potatoes for a brief period at a lower temperature preparatory to cold storage.

Singh and Mathur[11] have called attention to the importance of the humidity of the atmosphere as a factor conditioning the loss in weight in potato tubers. The general conclusion arrived at was that high humidities reduce the physiological loss in weight but stimulate sprouting.

During pre-dormancy, there is a rapid loss in weight due to transpiration as well as respiration. During dormancy, the loss of weight due to both these causes decreases but there is a remarkable increase in the loss in weight during sprouting. Evidently the suitability of R.H. will depend on the stage of tubers and duration of storage.

Singh, Mathur and Mehta[12] have presented data which indicate the presence of cellulose in potato sprouts. This observation is interesting in view of the controversy regarding the function of celluloses in plants. They are believed to be mainly structural materials and suggestions have been made that they act probably as storage materials also. Most of the loss in cellulose was attributable to the loss of zylan—a cellulosan-which is associated with most celluloses. The authors suggest that zylan, being in all probability less resistant than cellulose, is mainly digested by certain constituents of potato sprouts.

Singh and Mathur[13] have shown that many factors such as variety, manurial treatment, maturity at picking, and diseases are determinants of storage life of fruits. The growth curves obtained by plotting successive fresh as well as dry weights are of the usual sigmoid type. The high value of respiration is recorded first in young fruits and then it reoccurs at the onset of senescence. It has been found that irrespective of the stage of ripening at picking, winter-grown tomatoes show the usual 'climateric' rise during the colour change from orange to red. So far as the temperature is concerned, the storage life of the fruits was found to be the longest at 5.7° followed by 9.8° and 14.7°C. At a given temperature the storage life is the longest in fruits picked green as compared to those picked in the yellow and orange stages. The respiration curves obtained in fruits after transference from low to high temperature are divisible into two parts: (1) high R.Q. associated with a rapidly falling respiration intensity and (2) a value of R.Q. approximating to unity accompanying either a falling or a steady respiration rate.

Luthra and Cheema[14] noted, while investigating the metabolism and growth of malta oranges, that the respiratory activity gradually slows down from adolescence to maturity, despite the accumulation of carbohydrates. The respiratory activity shows a second high value at the climacteric stage. The relative growth rate and nitrogen content of the developing fruits show strict concomittance with respiratory activity. Reducing sugars, sucrose and total sugars steadily increase from adolescence to maturity. The reducing sugars are highest just before the climacteric rise in respiration. At no stage starch formation could be noticed either in the flesh or in the skin of the fruit. The total titratable acids increase gradually till the 170th day but fall down later. The total solids are highest in the beginning when the fruit is young but later on decrease on account of the progressive hydration which follows subsequently.

Leley, Narayana and Daji[15] have studied the physical and chemical changes occurring during the growth and ripening of the banana fruit. The main activity of the fruit during growth is concentrated round the synthesis and storage of starch, almost the whole of which is, however, converted into sugars during the process of ripening. The respiratory activity of the mature fruit is stimulated on harvesting and reaches the climacteric peak in about eight to ten days. The catalase activity of the pulp is greater than that of the peel during the process of growth.

Refrigerated Storage of Perishables

Efforts have been made during recent years to tide over the glut season, regulate the home markets and explore the possibilities of export of various perishables to foreign countries. In case the supply is regulated and the 'market-life' of various perishables is extended by application of refrigerated storage, the problem of their marketing both in India and abroad would be greatly simplified, as the regular and controlled supply is a pre-requisite to profitable marketing.

Some preliminary work on the storage of mango has been reported by Cheema and Ghandhi[14], who used one of the storage chambers in the Crawford Market, Bombay for their experiment. They found that the fruits of the *Alphonso* variety of mango could be preserved at 36° F to 40° F for about a month in satisfactory condition. Joshi and Rama Iyer[17] observed that ripe mangoes could be kept in cold storage for about

three weeks but the unripe fruits stored in the same condition did not ripen afterwards when removed to higher temperatures. From the study of the respiration of mangoes at different temperatures from 22° C to 5° C, Rao[18] has concluded that the best temperature of preservation of mangoes is 5°C and 10° C. At low temperature the ripening process is very slow, as indicated by the constant output of CO_2. These findings were confirmed by actual storage experiments.

Banerjee, Karmarkar and Row[19], investigating on the cold storage of mango, observed that mature fruit ripened slowly at low temperatures and pre-storage treatments did not help in prolonging the storage life of the fruit by retarding its decay. They found that in *Neelum* mangoes acidity values fell to a minimum after seven days, whilst total sugars rose to a maximum. Reducing sugars reached a maximum after 12 days by which time the fruit spoiled. At the storage temperatures of 50° F and 41° F., no appreciable alteration in acidity or reducing sugars occurred in 14 days. At 50° F, there was a rise in total sugars, but none at 41° F or 32° F during the same period.

Cheema and Dani[20] have defined four stages of maturity in *Alphonso* mango: (1) 'A' stage—The shoulders are in line with the stem and the colour of the fruit is oil green (2) 'B' stage—The shoulders outgrow the stem end and the colour is oil green (3) 'C' stage—The shoulders outgrow the stem end and the colour lightens and (4) 'D' stage—The flesh becomes soft and the blush develops. They also reported details in connection with the experimental exports of the *Alphonso* variety of mango from Bombay to London. Due to the fact that a more or less constant temperature of 45° F could not be maintained throughout the sea voyage, the results were not very encouraging. During recent years, however, small quantities of mangoes have been exported from Uttar Pradesh to England by air.

Cheema, Karmarkar and Joshi[21] found that fruits of 'A' stage maturity (green but just mature) and 'D' stage maturity (ripened on the tree) are unsuitable for cold storage. They, therefore, used fruits of 'B' and 'C' stages of maturity (green and mature, and green and fully mature) for their investigations. The 'B' stage fruits were found suitable for cold storage. Ripe yellow fruits (eating maturity) of all the varieties with the exception of two varieties turned brown on cold storage (30°F to 52°F), due to chilling. Green fruit of 'B' stage chilled at temperatures below 45°F refused to ripen when transferred to higher temperatures. It has been found that there is a correlation between the acid content of green fruit and the length of the storage life, the latter being short in the case of fruits with low acidity and long in the case of those with high acidity. *Alphonso* was found to be the best keeper in cold storage.

Karmarkar and Joshi[22] have studied the behaviour of onions under storage conditions. Storage does not affect the pungency of the onions but at 32° F., while the carbohydrate economy is affected, reducing sugars along with total sugars increase in amount.

Karmarkar and Joshi[23] have studied the respiration of *Alphonso* mangoes under different storage conditions. They found *inter alia* that (*a*) the decline in the respiratory rate was due not to the decrease in the sugars present but to the depletion of acids, (*b*) the values of the respiratory quotient indicated that the acids formed a part of the respiration substrate, (*c*) respiration was not affected by the reduction of pressure, (*d*) CO_2 upto 11 per cent had no effect on respiration and that (*e*) in some cases there was a considerable decrease in nitrogen in the respiratory chamber. Lal Singh and Abdul Hamid[24] studied the best method of storing Bartlett pears. They have found that the optimum temperature for pears to ripen is 60-70° F. Pears stored at 32° F must be conditioned at 60-70° F.

Mathur[25] investigated the following aspects of potato storage: (*a*) the physiological loss in weight of mature potatoes stored at different temperatures and relative humidity, (*b*) the effect of depth of piling on physiological loss in weight of tubers, (*c*) storage of seed and table potatoes, (*d*) effect of tuber size on storage life, (*e*) effect of storage temperature on starch, sucrose and reducing sugars in stored potatoes, (*f*) effect of mechanical injury to tubers on loss in weight during storage and (*g*) effect of heat treatment of potato tubers prior to storage. He

found the minimum loss at 41°F storage temperature. Seed potatoes stored at 50°F gave the maximum yield of tubers as compared with those stored at other temperatures.

Singh and Mathur[26, 27, 28] carried out studies to determine the rate of ripening, chemical changes and percentage of waste in two varieties of mangoes at 67-70°F. They recorded a temperature of 32-35°F and relative humidity of 80-90 per cent as optimum conditions for cold storage of tapioca tubers (*Manihot utilissima*), the approximate storage life being 6½ months. They also reported that cashew apples can be stored for a maximum period of 5 weeks at a temperature of 32-35°F and R.H. of 85-90 per cent. Anand and Johar[29] have observed that different varieties of raw mangoes intended for the preparation of chutneys can be kept for a maximum period of 40 days at 40-43°F and R.H. of 85-90 per cent. According to Singh, Kapur and Mathur[30], the optimum conditions for the cold storage of *Totapuri* mangoes are a temperature of 42-45°F and a R.H. of 85-90 per cent, the storage life being 7 weeks. The mangoes thus stored can be ripened at a temperature of 67-85°F. Mathur, Singh and Kapur[31] have recommended a temperature of 32-35°F and a relative humidity of 85-90 per cent for the storage of shell eggs. The eggs obtained from white Leghors and Barred Plymouth Rock breeds can be stored for 9 months under the above conditions. It has been reported by Mathur, Singh and Kapur[32] that seedling mangoes should be stored at 42-45°F with R. H. of 85-90 per cent. The mangoes intended for table use can be ripened satisfactorily in about 2 weeks at 62-65°F.

In their studies on the cold storage of two varieties of potato, *viz.*, up-to-date and Hybrid-9, Mathur, Kapur and Singh[33] observed no sprouting at the end of 24 weeks in potatoes stored at 32-35°F and 35-38°F. Considerable sprouting, however, occurred at 42-45°F and 47-50°F. The approximate storage life of potatoes under the optimum conditions *viz.*, a temperature of 35-38°F and R.H. of 85-90 per cent was found to be 9½ months. According to Mathur, Singh and Kapur[34], *Raspuri* mangoes can be stored for a maximum period of 42 days at 42-45°F in a green condition. *Badam*, *Alphonso*, can be stored only for 28 days at a temperature of 47-50°F.

Singh and Mathur[35] have recommended a temperature of 52-55°F and a R.H. of 85-90 per cent as the optimum conditions for the cold storage of Cavendish variety of bananas, the storage life being 22 days. They recommended the selected green and hard fruits for cold storage. Kapur, Mathur and Singh[36] have reported that a temperature of 59-87° F is suitable for the storage of onion sets, large size onions lose less weight during storage than small ones. They observed that a greater percentage of rooting and germination was found to be associated with a great loss of sucrose and reducing sugars. $KMnO_4$ treatment had no effect on the keeping quality.

Srivastava and Mathur[37] studied the economics of cold storage of Coorg loose skin oranges at 42-45°F with 85 per cent R.H. The spoilage was mainly due to *Penicillium italicum* and *P. digitatum*. Treatment of crates with lysol prior to storage reduced the spoilage and hence increased the storage life. The overall wastage was only about 10.4 per cent. Siddappa *et al.*[38] observed that seedless white grapes stored at 69-92°F and R.H. 45-92 per cent in crates lined with cotton wool keep well for about 9 days. At 32-35°F and R.H. 85-90 per cent, they keep well for about 7 weeks. Kirpal Singh and Mathur[39, 40] have reported that sapota keeps well for about 8 weeks at 35-38°F and 85-90 per cent R.H. and have a post-storage life of 3-5 days.

According to Mathur and Srivastava[41], Durion fruit (*Durio Zebithenus*, Murr.) keeps for 30-65 days at 39-42°F and 85-90 per cent R.H. depending upon the extent of splitting of the rind before storage, the post-storage life being 5 days. Kirpal Singh and Mathur[42] have reported that guavas keep well for about 4 weeks at 47-50°F and 85-90 per cent R.H. According to the same authors[43], the storage life of jack fruit is 3-6 weeks at 52-55°F and 85-90 per cent R.H. The edible bulbs can also be frozen at -20°F in a syrup of about 50° Brix containing 0.5 per cent citric acid and then can be stored at 0°F for over a year. The taste and flavour of the stored bulbs were just like those of the fresh ones. In a further study on the cold storage of mangoes, Singh *et al.*,[44] have reported that *Totapuri*

mangoes can be stored for about 7 weeks at 42-45°F and 85-90 per cent R.H. and can then be ripened satisfactorily at 67-70°F. Data for total soluble solids, acidity, ascorbic acid and respiration rate are included.

Srivastava and Mathur[45] reported that field beans (*Dolichos lablab*) can be stored for about 3 weeks as pods and for one week as seeds at 32-35°F and 85-90 per cent R.H. The storage diseases are due to two fungi, *viz.*, *Colletotrichum lindemuthianum* and *Rhizopus nigricans*.

Das and Lal[46] reported the physical and chemical changes in water from tender cocoanuts stored for 7 weeks at 42-45°F.

Srivastava and Mathur[47] reported that the optimum temperature for cold storing Langsat (*Lansium domesticum*) was 53-55°F and R.H. 85-90 per cent, the storage life being 14 days. At lower temperatures, freezing injury was remarkable and the decay organisms were found to be *Rhizopus nigricans* and *Aspergillus luchuensis*. Mathur[48], reviewing the position of refrigerated preservation of perishable foods in India, laid emphasis on introduction of more refrigerated wagons on Indian railways. Pruthi and Lal[49] reported the cold storage temperature for purple passion fruit (*Passiflora edulis*) at 42-45° F and R.H. 85-90 per cent and the storage life being 4-5 weeks. Dipping fruits prior to storage in formaldehyde (2 per cent), iodine (2 per cent), boric acid (5 per cent) and alcohol (95 per cent) proved to be effective in reducing the spoilage.

Srivastava and Mathur[50], studying the role of relative humidity on cold storage of onions, found that they can be cold stored at 32-35° F and 60 per cent relative humidity for 8 months as against only four months at the same temperature and 85-90 per cent R.H. It was further reported that *Aspergillus niger* and *Rhizopus nigricans* were mainly responsible for the spoilage at 85-90 per cent R.H., while *Penicillium sp.* was found at 70 per cent R.H. Mathur *et al.*[51] reported that shelled as well as unshelled peanuts could be stored for 9 months at a temperature of 32-35° F and a relative humidity of 85-90 per cent. As shelled nuts occupy approximately only 40 per cent of the storage space as compared to unshelled ones, it is preferable to cold store shelled nuts. A parallelism was observed between the changes during storage in the moisture contents of the kernels and the acid values of the extracted oils and to a less degree, the changes in the peroxide values. A free fatty acid content exceeding 1 per cent was found to be associated with seeds of low germination capacity.

Srivastava and Mathur[52] reported that the cold storage life of yellow and pink varieties of sweet potatoes grown at Mysore is three months at 52-53° F and 85-90 per cent R.H. Iyengar *et al.*[53] showed that the method of packaging for betel leaves depended on the temperature of storage. For example, in the temperature range 42-91° F, polyethylene bag with no respiration vents was adequate but at a higher temperature range of 102-105° F, jute bags lined with polyethylene film with 24 respiration vents were found to be the most suitable package. This study demonstrated very clearly that for the storage of fruits, vegetables and other commodities of a similar nature, temperature was a more important factor than the method of packaging. Mukerjee[54] reported that semi-mature *litchi* (*Litchi chinensis*) fruits could be stored for 3 weeks at a temperature of 45° F without the development of any discolouration on the skins of the fruits.

Srivastava and Mathur[55] isolated 24 different types of micro-organisms from the cold storage rooms and conducted pathogenecity tests for these micro-organisms at different temperatures. They also found a direct correlation between the spore load on fruits and their storage life. Majumdar *et al.*[56] reported that tapioca roots preserved at room temperature could be used for starch manufacture for industrial purposes. Mathur *et al.*[57] reported that bottle gourd can be cold stored for about two months at 67-70° F and drumsticks for about 4 weeks at 47-50° F. Yam can be stored at room temperature for about 6-8 months under the Mysore conditions.

Srivastava and Mathur[58] reported the optimum conditions of refrigerated storage for twelve different varieties of mangoes and also their storage life. If the ripening period of 2 weeks at 67-70°F is added to the cold storage life, the total cold storage life varies between 6-10 weeks for the various varieties. They reported that the application of 7 per cent wax emulsion extends

the cold storage life by 12.5 per cent and post-storage life by 80 per cent.

Srivastava and Mathur[59] investigated in detail the causes for the spoilage of mangoes during transit, storage and marketing, and recommended certain remedial measures. It has been reported that, generally, mangoes suffer from Anthracnose caused of *Colletotrichum sp.* or soft rot caused by either *Aspergillus* or *Penicillium sp.* The fruit may have a latent infection which develops during transit or storage under suitable conditions. High microbial load in the fruit also results in the spoilage of the fruit. It has been found that mango trees sprayed with 3:3:50 Bordeaux mixture at flowering time reduces the latent infection.

Mathur and Srivastava[60] reviewed the present position of refrigeration industry in India and the work done at the Central Food Technological Research Institute, Mysore on the cold storage and freezing of fruits and vegetables. Besides, tabulated data on the optimum storage temperature, humidity and storage life of a number of fruits and vegetables, the economics of a semi-commercial trial on the cold storage of mandarin oranges and the economics of freezing preservation of mangoes have been discussed.

Pruthi, Srivastava and Lal[61] reported the nature of microbiological spoilage as well as its control in purple passion fruit (*Passiflora edulis*) during refrigerated storage. The fungi responsible for spoilage were: *P. expanscum*, *A. niger*, *F. oxysporum* and *R. nigricans*. Packaging and storage of the fruit in polyethelyne bags and wooden crates treated with 5 per cent lysol solution have been found to be effective in preventing the spoilage.

Mathur and Srivastava[62] reported the optimum conditions and cold storage life of the commodities, such as betel leaves, ginger, tapioca tubers, 'parval' (*Trichosanthes dioca*) etc., so far worked out at Central Food Technological Research Institute. They also reported the effect of fungicide impregnated wrappers and skin coatings with a view to extending the normal as well as the cold storage lives to facilitate transportation and to regulate the market. Some of the most important lines of work, *e.g.*, use of hormones to inhibit sprouting and prolonging ripening process, freezing of fruits and fruit juices, smoke curing of garlic bulbs are packaging and transport of fruits and vegetables, which are being tackled at present at Central Food Technological Research Institute, Mysore have also been elaborated.

Refrigerated Gas Storage

This system of preservation of perishables has proved to be superior to ordinary cold storage and it has been shown that it imparts 2/3 more life to apples, pears and bananas[63-65]. In India, some work of fundamental nature has been conducted, and consolidated experiments in this line are now in progress at the Central Food Technological Research Institute, Mysore.

Rafique[66], in his analytical studies on the respiration of apples in low concentrations of O_2 has shown that 'Oxidative mechanism' adapts itself to the altered supply of oxygen much more rapidly than the mechanism which is responsible for the activation of pre-glycolytic phase as a consequence of the change of a major portion of products of glycolysis to anaerobic component 'NR'.

Singh and Mathur[67] found that in massive structures like ripe tomatoes, the superficial tissue offers great resistance to the movement of gases and that the total CO_2 production during metabolism is not the same as that evolved at the surface. Considerable amounts of CO_2 accumulate in the fruit tissue during ripening, coming down during the climactric phase and then rising gradually. The amount of gas extracted from the fruits gradually rises with increase in the rate of respiration up to the time when the peak value characteristic of the climactric stage is obtained, after which a rapid decline is discernible. Evidently, during the climactric stage the resistance offered by the superficial tissues to the movement of gases, CO_2 outwards and atmospheric gases inwards, is lessened, thus augmenting not only the rate of CO_2 production but also that of O_2 intake. The suggestion is made that the climactric rise in tomatoes is in all probability due in part to the establishment of a steep gradient of CO_2 concentration as also to an increase in the permeability of the superficial tissues to the diffusion of gases. Although the superficial CO_2 evolved declines after the climactric, the dissolved CO_2 in the fruit progressively increases.

This indicates an active rate of metabolism following the climactric rise and is probably explainable on the basis of the lowered permeability of the superficial tissues to the diffusion of gases.

Karmarkar[68] reviewed the work on refrigerated gas storage of fruits and vegetables. Sircar[69], while reviewing the important factors in fruit preservation and the methods employed for successful storage of fruits, stressed the usefulness of refrigerated gas storage over the cold storage methods. The author rightly observed that if the wide possibilities of gas storage for fruits are to be exploited, research on the fundamental physiological problems should be encouraged. Storage under scientifically controlled conditions should be carried out before embarking on adventures of a commercial nature and attempts made to define the requirements of the fruit in view of the special regard to atmospherical, thermal and pre-storage factors.

Kar and Banerji[70] studied the behaviour of the available substrates in *Psidium guava* and found that the effect of ethylene was more marked on the fruits gathered at maturing stage. Equally interesting are the contributions on the metabolism and growth of Malta oranges by Luthra and Cheema[71], and on the effect of ethylene and sulphur dioxide on fruits of *Mangifera indica* by Ranjan and Jha[72].

Mathur[73] has reviewed the present position regarding the refrigerated storage of apples and bananas. He has stressed the importance of respiration studies with regard to the cold storage of fruits and vegetables. At the Central Food Technological Research Institute, Mysore, studies on the refrigerated gas storage of mangoes and bananas are in progress. Many interesting results have recently been obtained on the oxidative pathways in these fruits during gas storage.

Extension of Storage Life of Perishables

Most of the fruits and vegetables being seasonal, they are subject to heavy spoilage due to glut. Proper treatment of such perishables, which will enhance their storage life and reduce spoilage during transit, will go a long way in regulating the market and bringing more premium to the growers and merchants. To achieve this objective, research work on various commercial fruits and vegetables is going on for the last six years at the Central Food Technological Research Institute, Mysore, with a view not only to regulating the home market but also finding market in foreign countries. In this direction, various skin coatings, wrapping with fungicide impregnated wrappers and post-harvest hormone treatments, have been used. These treatments reduce rates of respiration and transpiration, reduce the spore loads and delay the ripening process, thereby extending their storage life and combating the spoilage during transportation.

Effect of various Skin Coatings and Wrappers

Srivastava and Mathur[74] evaluated the effect of various skin coatings and fungicidal impregnated wrappers on Golden Delicious variety of apples and found that the fruits with ten per cent alcoholic solution of castor oil shellac and wrapped with tissue paper impregnated with 2 per cent lysol solution proved to keep better than those which were given other treatments. Such treated fruits could be kept for $5\frac{1}{2}$ months at 35-38°F as against 4 months in the case of control. Further, such treated fruits exhibited 16 days of post-storage life as against only 9 days in the case of control. They also recorded that storage of apples in polyethylene bags with respiration vents gave very promising results.

Srivastava *et al.*[75] investigating the efficacy of various skin coatings, *viz.*, Cermul C, Zenith processing wax, Prerox D—a mineral oil, and various wrappers found that the storage life of mangoes, oranges, pomegranate and sapota was increased by about 50 per cent, if they were dipped in wax emulsion containing 7 per cent solids under the Mysore conditions. The wastage of oranges and mangoes was considerably reduced, if they were wrapped in diphenyl impregnated wrappers containing 30-40 mg. per 10 square inch of tissue paper.

Bose and Basu[76] have observed that *Fajli* mangoes can be kept for 42 days at 55°F and 90 per cent R.H. by dipping them in 50 per cent paraffin wax at 80°C for 10 seconds. The untreated mangoes rotted within 14 days.

Srivastava, Date and Mathur[77] treated *Neelum* mangoes with 0.25 per cent diphenyl containing 6 per cent wax-free shellac and found that this

treatment reduced the wastage percentage and delayed the ripening. Subramanyam and Mathur[78] studied the effect of treatment with fungicidal wax emulsions (containing 1.6 per cent petroleum wax, 1.24 per cent resin, 0.27 per cent oleic acid, 0.68 per cent triethanolamine and 0.21 per cent orthophenyl phenol) alone and in combination with methyl-naphthalene acetate (MENA) on storage behaviour of potato. It was shown that physiological losses in weight and also those due to respiration were least when treated with emulsion containing MENA. Sprouting was also the least in such treated lots.

Mathur and Srivastava[79] found that coating of mango (three varieties, *viz.*, *Padri*, *Neelum* and *Totapuri*) with a wax emulsion in water increased storage life by 50 per cent at 72-82°F and R.H. 65-90 per cent. When only top one-third was treated with mineral oil, similar improvement was observed. Mathur and Subramanyam[80] showed that the storage life of *Badam* (*Alphonso*) mangoes could be increased by about 50 per cent in non-refrigerated storage after treatment with fungicidal wax emulsion. The treatment was found to lessen the physiological losses in weight, increase the retentions of vitamin C and moisture, delay ripening and decrease the percentage wastage. Treatment with the same wax emulsion was shown by Subramanyam and Mathur[81] to increase the storage life of tapioca roots from 2-16 days at room temperature (73-81°F and R.H. 62-77 per cent).

Srivastava and Mathur[82] reported that wrapping the mango fruit with diphenyl wrappers at the rate of 30-40 mg. per wrapper does not impart any extraneous flavour to the fruit.

Post-harvest Hormone Treatment

Dutt and Guha Thakurta[83] investigated the effects of different chemical and gas treatments on shortening the dormancy of freshly harvested tubers of potato varieties, Nainital and Darjeeling red round. Treatment with 2 per cent solutions of sodium, potassium and ammonium thiocyanate and 1 per cent ethylene chlorhydrin shortened the dormancy of half-cut tubers by 5-6 weeks. Similarly vapour treatment with ethylene chlorhydrin (0.5 c.c./l.) was effective on half-cut tubers. It was also observed that the resting period of immature tubers was shorter than that of the mature ones. The effect of CO_2 in breaking the dormancy was attributed to direct stimulatory action of the gas and not to anaerobiosis indirectly brought by absence of oxygen.

Venkataratnam[84] studied the influence of β-naphthoxyacetic acid spray on fruit development in 3 varieties of South Indian mangoes. Emasculated flowers developed into fruits of size of a marble on treatment with this growth-regulator, but then dropped off and, on examination, parthenocarpic development was found. Saptharishi and Azariah[85] reported that the use of methyl ester of naphthaleneacetic acid (*Barsprout*, manufactured by American Cyanamid and Co.) at the rate of 2 g. of *Barsprout* per pound reduced loss of weight of potatoes in storage to only 24 per cent as against the loss of 71 per cent in the case of control ones.

Srivastava and Mathur[86] reported that potatoes can be successfully stored at room temperature without sprouting by treating them with Cermul C7 per cent solids and terpeneol.

Mathur and Srivastava[87] have observed that the terpeneol treatment suppresses sprouting, the effect being most marked at 52-55°F. Mathur and Singh[88] have suggested the use of growth inhibitors to reduce sprouting in stored potatoes. In their preliminary studies on the effect of hormones on the ripening of fruits, Date and Mathur[89] found that post-harvest treatment with 2, 4, 5-T at 50-500 p.p.m. retarded the development of the skin colour in mandarin oranges and application of 2, 4, 5-T and maleic hydrazide at 250 p.p.m. showed similar effect with regard to *Badam* (*Alphonso*) mangoes.

Mathur and Srivastava[90] showed that pre-harvest foliage sprays of MH_{40} inhibited rooting and sprouting in onion bulbs stored at 32-35°F and 80-90 per cent R.H. Mathur *et al.*[91] reported a noteworthy feature that maleic hydrazide produces more pronounced inhibitory effects at a higher temperature range than at a lower one. Preharvest foliage sprays of maleic hydrazide reduced the wastage due to fungus diseases in onion bulbs stored at both the temperature ranges investigated, although the effect was greater in the lower range.

Freezing Storage

This system of preservation is gaining momentum in U.S.A., U.K. and other foreign countries so much that the sale of frozen foods is much greater than that of canned or fresh foods. In India, systematic research work has been started recently at the Central Food Technological Research Institute, Mysore and the results have been extended to the industry. Recently, the industry is evincing interest in exporting frozen mango slices in syrup to foreign countries.

Srivastava and Mathur[58] reported a detailed account of freezing preservation of mangoes. They suggested that the mango slices could be frozen in 40-50° Brix syrup with 0.5 per cent citric acid and 0.05 per cent ascorbic acid by weight and the storage life at 0°F was $10\frac{1}{2}$ months depending on the variety. They also reported that the addition of 0.1 per cent monosodium glutamate improved the flavour of *Padri* mangoes.

Mathur and Srivastava[69] worked out the economics of freezing preservation of mango stored for 9 months at 0°F and found that one pound of frozen mango will cost approximately Rs 1.75 and the net profit will be about 22 per cent.

Srivastava and Mathur[92] reported the freezing preservation of *Padri* mango slices in syrup, pulp and whole mango. This variety has a strong flavour and keeps very well in frozen state for a period of twelve months. Some lots which were kept till a period of 28 months retained the fresh flavour.

Mathur, Singh and Srivastava[93] gave the details of the preparation, packaging, freezing and behaviour during storage at 0°F of some fruits and fruit products, *viz.*, apple, grapes, jack fruit, litchi, mango, orange and pineapple. It is reported that the losses of ascorbic acid in the various frozen fruit products during storage of 0°F were not significant.

Dehydro-Freezing Storage

The conception of dehydro-freezing is rather of recent origin. This process involves partial removal of natural water prior to freezing of fruits and vegetables to improve their keeping quality and to save space in storage. The USDA Western Utilization Research Laboratory has obtained a patent on this method. In U.S.A., commercial adoption of this method of preservation is gaining momentum after several years of laboratory and pilot plant research on the subject. In India, only recently, some work has been started at this Institute.

Srivastava and Mathur[94] conducted some experiments on dehydro-freezing of Golden Delicious variety of apple rings and found that dehydration to 50 and 60 per cent level and freezing gave a storage life of nine months at 0°F. They were packed in card board cartons. Srirangarajan[95] reported that bitter gourd slices packed in cellophane at 86.9 per cent moisture level and polyethylene bags at 81.0 per cent moisture level were successfully dehydro-freezed. A slight change in taste was observed in the product packed in cans at 30.0 per cent level. Further work is in progress in this direction.

Smoke Curing

In India the practice of smoke curing had been followed from times immemorial in order to improve the keeping qualities and impart desirable organoleptic properties to the perishable commodities. But it is only recently that attempts have been made to control the various steps in the process to obtain a better product. The resultant desirable qualities in smoked foods are due to (*i*) partial dehydration, (*ii*) incorporation of antioxidants, (*iii*) impregnation of antiseptic constituents, (*iv*) effect of heat on micro-organisms (*v*) improvement in organoleptic properties, etc. Generally, for the production of smoke, shavings and sawdust of hard woods are used. Jenson[96] attributed the preserving properties of smoke to aldehydes, phenols and aliphatic acids. Pettit[97] reported that oak dust smoke contains formaldehyde, acetaldehyde, furfuraldehyde, acetone deacetyl, methyl and ethyl alcohols, formic, acetic and higher fatty acids as well as phenols and fat. According to Hess[98], formaldehyde is the chief bactericidal constituent of smoke.

Srivastava and Mathur[64, 99] designed and fabricated one smoking chamber in collaboration with the Engineering division of the Central Food Technological Research Institute, Mysore, for smoke curing of garlic bulbs. They reported that the cumulative percentage physiological

loss in weight due to respiration was lower, the longer the duration of smoke curing. This was attributed to a decreased permeability to gases of the outer skin of the garlic bulblets due to the impregnation of the constituents of the smoke. They further reported that the microbial spoilage was also inhibited to some extent due to smoking. The bulbs which were smoke-cured for 7 hours were found organoleptically acceptable and were better than the controls. The storage life of such treated garlic bulbs was 38 weeks at room temperature (71-86°F and 47-80 per cent R.H.) as against 10 weeks in the case of control ones, on 10 per cent wastage basis.

Srivastava and Mathur[100] also found that the banana after cold storage ripens very well, if smoke-cured with dry banana leaves in the smoke chamber. This line of work is also being extended to various dry fruits, fish and meat at the Central Food Technological Research Institute, Mysore.

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STORAGE AND PRESERVATION OF FATTY FOODS

By N. S. Kapur and H. C. Srivastava

(*Central Food Technological Research Institute, Mysore*)

The field of fatty foods includes the edible fatty nuts, fats and oils. In India considerable work has been done on the storage of oils and fats but a very scanty literature is available regarding the storage of fatty nuts. Recently, work in this direction has been started at the Central Food Technological Research Institute, Mysore and a successful method of storage has been evolved for preserving cashew kernels, the principal nut exported from this country. The important fats and oils used in this country are groundnut oil, cocoanut oil, mustard oil and *ghee*. In some parts of the country other oils are also used.

Storage behaviour of Nuts

1. *Groundnut:* The important findings[1] on the development of free fatty acids and the incidence of insect attack during storage of groundnuts are: (*i*) the crop, if harvested after it is fully mature, will have a lower percentage of shrivelled

kernels and higher oil content with a low percentage of fatty acids, (*ii*) though the groundnut kernels of the summer crop yield 2-3 per cent more oil than the rain-fed crop, the development of free fatty acids and insect attack were more prominent in the summer variety, (*iii*) in the kernels dried to less than 5 per cent moisture content, the percentages of free fatty acids and insect attack were much less than in kernels having 7-8 per cent moisture, (*iv*) groundnut pods have better storage properties than groundnut kernels and, if the kernels have greater percentage of splits after decortication, the tendency for deterioration is more marked and (*v*) bagged groundnut kernels when piled up to a maximum of 15 units during storage using a dunnage material do not deteriorate. Venkatanarayana[2] recommends that if kernels are intended to be stored for long periods they should be obtained from the rain-fed crop, dried to a moisture content below 5 per cent and carefully decorticated so as to have least splits and should not be stacked up to more than 10 units on the soft sandy beds. Seshadri *et al.*[3] have reported that harvesting the crop when fully mature and thoroughly drying the pods yields the finest quality of oil. Curing by stacking is also recommended. Mathur *et al.*[4] have found that groundnut kernels can be successfully cold stored for one year.

2. *Cashewnuts:* Iyengar and Kale[5] reviewed the problems of cashewnut industry in India and described different methods of roasting and processing of the kernels. Kapur *et al.*[6] described the method of processing, packing and storage of cashew kernels. They also reported the chemical composition of cashew kernels. Prasad *et al.*[7] tried eleven different oils for roasting of cashew kernels and found the refined groundnut oil and hydrogenated groundnut oil to be the best. The storage life of such roasted kernels was reported to be six months. Prasad and Mathur[8] reviewed the status of cashewnut industry in India and reported that cashew kernels exported in 1953 were valued at Rs 12.76 crores. Prasad and Mathur[9] have found that roasted and salted cashew kernels can be stored without any deterioration for 6 months when vanaspati or refined groundnut oil is used as the roasting medium.

Two processes have been developed at the Central Food Technological Research Institute, Mysore, for the storage of roasted and deep fried cashew kernels and they are covered by patents, *viz.*, Indian Patent Nos. **49838** and **53319**[10]. As a result of semi-commercial trials, the approximate cost per unit in each process has been arrived at.

Prasad and Mathur[11] found a temperature of 160°C and a dip for 80 seconds to be optimum for deep fat frying of cashew kernels. The percentage of moisture lost during frying and the percentage gain in weight decreased. The oil uptake by kernels was the same at all the frying temperatures. It was found that the moisture loss from kernels is greater if the proportion of kernels with respect to the given quantity of oil is reduced. On the other hand, the oil uptake by the kernels is increased when the proportion of kernels with respect to a given quantity of oil is reduced. The deterioration is far greater in the case of peanut oil as compared to *vanaspati*.

Storage of Hydrogenated and Unhydrogenated Groundnut Oil

Roy and Guha[12] have found that amongst the blended hydrogenated groundnut oil samples (all melting at 37°C) those having a greater proportion of refined groundnut oil showed higher rates of peroxide and acid formation. The straight hardened groundnut oil appeared to be more stable than even the blended sample containing the least amount of refined oil. The stability of the sample was roughly inversely proportional to the linoleic acid content. Oleic acid, unlike linoleic acid, did not influence the stability adversely as it was observed that the straight hardened oil having the highest proportion of oleic acid did not play any significant part so long as linoleic acid was present. The increase in acid values of the blended oil was usually small. Though the acid value has probably no direct relation to peroxidation, the rate of increase of acid value was roughly proportional to that of peroxide value. Antioxidants usually suppressed acid promotion slightly and peroxide formation considerably. The peroxide value of the blended samples stored in sealed tins rose initially but decreased after 2 or 3 months.

Roy[13] in a comparative study on the stability of crude, refined and hydrogenated groundnut oils has found that all hydrogenated oils are more stable than unhydrogenated ones and the fat melting at 41°C is superior to that melting at 37°C. The refined oils are easily susceptible to an acidity as against crude oil, but the protection factor of ethyl gallate is more pronounced in the case of refined oil. Further, the addition of 5 per cent hydrogenated sesame oil to *vanaspati* affords better protection than refined sesame oil. Patel and Magar[14] have found that the stability of hydrogenated fats could be correlated with the extent and nature of fatty acids in them. Roy[15] found that vitamin A acetate is most stable in vanaspati when it contains crude and hydrogenated sesame oil. The presence of ethyl gallate, however, checks the instability of oils due to vitamin A acetate. The temperature and duration of heating have a tendency to destroy vitamin A acetate. The maximum retention of vitamin A was found with straight hardened oil and the least with refined oil. Mathur *et al.*[16] studied the deterioration of vitamin A when added to hydrogenated fat and sesame oil. Chitra and Khale[17] found that the loss of vitamin A in hydrogenated groundnut oil was about 25 per cent when stored in open tins for one month, but when stored in closed tins the same loss occurred after six months. The deep frying loss was 90 per cent while heating loss was only 20 per cent.

Storage of other Oils and Oilseeds

Narayana Rao and Swaminathan[18,19] studied a variety of niger seed grown in Mysore and one variety of safflower seed grown in Bombay with respect to the composition of the seed kernel and oil. The stability of crude, refined and bleached oils was studied by A.O.M. tests as well as by storing in aluminium and tin containers. The results indicate that both the oils are easily susceptible to oxidation and are not as stable as groundnut oil. The instability of niger seed oil is due to the high percentage of linoleic acid glycerides[20]. Subbarao and Gopala Rao[21] have found that niger seed oil decolourised by photochemical methods develops oxidative rancidity at an accelerated rate even when exposure to light is prevented.

Gupta and Aggarwal[22,23] found that *Kamala* seeds when stored in bags deteriorate quicker than those stored in tins and storage in either case can last for about six months. They have also found that oliogenous plant materials can be stored for commercial solvent extraction without any deterioration by passing the harvested material through a continuous drier until the moisture is reduced to 1-3 per cent. The drier suggested consists of anodized aluminium tunnel heated by infra-red lamps. The materials thus treated give 98 per cent oil with an acidity of 0.7 per cent. Rao and Swaminathan[24,25] and Subrahmanyan *et al.*[26] have found that stability of cottonseed oil is due to the gossypol content which possesses an antioxidant property. Even addition of BHA and α-dodecyl gallate at 0.02 per cent level to refined oil (from which gossypol and phosphatides are removed) did not prevent the development of rancidity. According to Krishnamurthi *et al.*[27] winterization did not affect the stability of cotton seed oil. Urs *et al.*[28] have found that acidity in mustard oil was more when stored at 37° and 50°C in tin or glass containers than in galvanized iron containers, as zinc in the latter neutralised a part of the acidity. However, peroxide value was the least in glass containers as the metals acted as pro-oxidants.

Srivastava and Rao[29] ascribe the rapid deterioration of *mahua* seed oil to an easily oxidisable highly unsaturated hydrocarbon.

Aiyadurai[30] found that addition of salt and *jaggery* to coconut oil improves its keeping quality while storage in red coloured bottles accelerates deterioration.

Krishnamurthi *et al.*[31] found the rate of development of rancidity in different oils used for making pickles; in ascending order it is coconut, groundnut, sesame and refined groundnut oil.

Sen Gupta[32] has found that bleaching of oil lowers its stability. The acidic clays increase acid value, lower peroxide value and introduce triene conjugation while the neutral clays do not affect the oil. Conjugation by bleaching does not occur in mono-unsaturated acids.

Storage studies on Ghee

Paul and Shahane[33] have found that raw milk gave *ghee* with a higher proportion of fatty acids than heated milk. Ramachand and Ahmad[34] found that storing *ghee* at smoking temperature lowered Reichart, Polenske, Krischan and iodine values but increased refractive index. Mukherjee[35] found that high humidity slightly retarded rancidity in *ghee*. Lalitha and Dastur[36] found that *ghee* made by local methods developed rancidity much more readily than *ghee* made in creamery. Initial high free acidity in *ghee* leads to further deterioration. Addition of ethyl gallate at 0.02 per cent level was found to be effective in checking oxidative deterioration but did not control the formation of free fatty acids. In case of creamery *ghee*, off-flavour was observed even at lower peroxide value. The peroxide value was pronounced when *ghee* was made at higher temperature. Sokkary and Zaki[37] found that *ghee* obtained from goat milk was least susceptible to oxidative rancidity as compared with that from cow, buffalo and sheep. Raju and Varadarajan[38] found that treatment of *ghee* with lime retarded development of acidity and rancidity for a long period but the *ghee* gave a burnt taste to fried things. Mitra[39] reported that butter fat did not turn rancid for six months if air was excluded completely or an inert gas was substituted in the head space of the container.

Basu and Bhattacharya[40] suggested that vitamin A in ethyl oleate could be protected by phenolic antioxidants with one or more free phenolic hydroxyls. Narayanan *et al.*[41,42] have found that *ghee* from cow's milk fortified with vitamin A is more stable than that from buffalo milk. The loss of vitamin A was maximum in mud pots followed by tin, aluminium and least in glass containers. The extent of destruction of carotene was more or less parallel with that of vitamin D in *ghee*. Shroff *et al.*[43] found that under normal conditions of clarifying *ghee* there was no loss of vitamin A in normal or fortified *ghee* or colourless fat but when heated at higher temperature there was destruction. The aluminium container destroyed all vitamin A but the rate of destruction was less in the iron vessel. Fresh *ghee* was more resistant to loss of vitamin A than the aged one.

Peroxidants, Antioxidants and the Mechanism of Oxidation

Mukherjee[44] found that the effect of metals was the least as pro-oxidant when it was confined to the aqueous phase. Hasiani and Saletore[45] reported the following order of effectiveness of certain metals as pro-oxidants: lead, zinc, copper, aluminium, silver and stainless steel. The oxides of these metals are more pro-oxidant in nature than the metals themselves. Sharma and Khan[46] studied the effect of metals and their oxides on the development of rancidity in sesame oil.

Saletore and Harakare[47,48] traced the poor stability of sesame oil to certain pro-oxidants which could be removed by adsorption on alumina. Treatment with charcoal removed antioxidants and accelerated rancidification. Saha *et al.*[49] found that activated bentonite was the most efficient adsorbing material for reducing the peroxides in the rancid oils and fats.

Bose and Subrahmanyan[50] have published a review on the antioxidants. Sahasrabudhe[51] has evaluated eight common antioxidants at 0.01 to 0.10 per cent level and has found that butylated hydroxy anisole (BHA) and propyl gallate are the most effective singly as well as in mixtures with citric acid and lecithin. Roy[52] found that combination of citric and tartaric acids when used as synergists increased the antioxidant properties of the naturally occurring phenolic substances in crude oils, while the protection was least with hydrogenated oils and intermediate with refined oils.

Mukherjee *et al.*[53] found that *l*-ascrobyl esters, laurates, myristates, palmitates and stearates, when added to *ghee* to the extent of 0.01 per cent more than doubled the induction period. α-Tocopherol (0.005 per cent) and ascrobyl palmitate (0.01 per cent) in combination were more effective than 0.005 per cent ethyl gallate. Banerjee[54] found that NDGA afforded better protection to sesame oil than propyl gallate. Patel and Srinivasan[55] have recommended isobutyl gallate and tartaric acid as protective agents for vitamin A in oils. Sethi and Agarwal[56] have indicated that heating the oils with spices and condiments to high temperatures could extract the antioxidant principles from them and were

not destroyed at frying temperature. Hasiani and Saletore[57] have found that acacatachin, a crystalline product obtained from ethyl acetate extract of *katha* prevents vegetable oils turning rancid. The protection factor is higher with refined than with raw oils.

Kapadia and Magar[58] found that antioxidants added to the oils before frying were completely destroyed during frying. At elevated temperatures the frying fat undergoes hydrolysis, polymerisation, loss of resistance towards rancidity, foam development, colour and flavour changes. Kapadia and Aggarwal[59] found that hydroquinone at 0.6 to 1.0 per cent level added to benzene or ether extracts of *kamla* seed oil maintained its original coating characteristic.

Kartha[60] observed that antioxidants not only checked the abscription of oxygen but also destroyed some of the peroxides present and the destruction might likely take place during induction period also.

Bose and Subrahmanyan[61] studied the mode of development of peroxides, acidity and attendant changes in freshly extracted groundnut and cocoanut oils when exposed in thin layers to the atmosphere at different temperatures. The rate of development of rancidity in both the oils was practically of the same order. The peroxide number rose steadily and then fell to some extent towards the end of the storage period. The extent of accumulation of peroxides was lower at higher temperatures than at lower temperatures although oils at higher temperatures developed more pronounced rancid odour. The acid value slightly increased while the iodine and saponification values slightly decreased. They[62] found that the peroxides were intermediary unstable compounds in the chain of oxidation. If they are decomposed at a faster rate than they are formed, the peroxide value decreases with increasing rancidity. At elevated temperatures, the rate of decomposition is particularly rapid and hence the peroxide test cannot be a strict measure of rancidity. The other tests *viz.*, Issoglio's test and Kries test also fail to estimate the extent of rancidity because they are based on the detection of aldehyde products. The amount of aldehyde formed in a product is not necessarily in direct proportion to the degree of rancidity.

Kartha[63, 64, 65] has identified the different antioxidants in oils by means of their characteristic behaviour during the induction period. The stability index of butter fat has been determined by exposing the sample to air on a glass plate and measuring the time required for the samples to record a certain gain in weight. Auto-oxidation in the presence of antioxidants produced non-reactive and non-catalytic peroxides but in the absence of antioxidants both non-catalytic and catalytic products were formed as indicated by the increased rate of oxidation after induction period. Also there was no decrease in the iodine value of auto-oxidising fats in the presence of antioxidants. During induction period the formation of peroxides depends not only on the nature of the unsaturated acids but also the number of unsaturated molecules which in turn determine the rate of formation of activated peroxides. After the destruction of antioxidants the formation of peroxides depends on the nature of unsaturated fatty acids. Naegamwala *et al.*[66] found that the first reaction during oxidation was the formation of hydroperoxides which were comparatively stable. The presence of free acids, however, tends to decompose hydroperoxides with the formation of hydroxyl compounds; decrease in iodine value was also observed. It indicates that the formation of small quantities of ring peroxides at the double bond, but, being unstable, they immediately break up.

Saletore[67] has proposed a new theory that nitrogen fixation by fats is fundamentally responsible for rancidity. Mukherjee[68] was able to isolate C_9 compounds from the auto-oxidation products of methyl oleate. He also studied the kinetics of auto-oxidation of oleic and linoleic acids with particular reference to oxygen consumption and changes in characteristics. The function of the α-methylene group in the process was discussed.

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PROCESSED PROTEIN FOODS OF VEGETABLE ORIGIN FORTIFIED WITH VITAMINS AND MINERALS

By V. Subrahmanyan, R. Rajagopalan, M. Narayana Rao and M. Swaminathan
(Central Food Technological Research Institute, Mysore)

Dietary surveys conducted over a large part of the country during the past two decades have revealed that the diets consumed by the majority of people in different parts of India are deficient in various important constituents, such as proteins, minerals and vitamins[1, 2]. In the case of proteins not only the quantity is often low but the quality is also generally poor[3]. The consequences of these dietary deficiencies are strikingly seen in the case of the vulnerable groups, *viz.*, weaning infants, young children and expectant and nursing mothers[4]. The continued undernutrition and malnutrition of these groups has affected successive generations through poor rates of growth, reduced capacity for work and low resistance to disease. There is abundant evidence to show that the weaning stage is perhaps the most critical when considered from the point of adequate nutritional requirements. The weaned infants and young children develop deficiency diseases in a short time when fed on inadequate diets[4]. In actual practice the infants belonging to poor parents change over from mother's milk which is almost a complete food, to a predominantly cereal diet deficient in many dietary essentials. Consequently, there is a high incidence of deficiency diseases among pre-school children due to lack of vitamins, minerals and protein[4]. This is inevitable owing to the scarcity and high cost of protective foods like milk and the low purchasing power of the people. The deficiencies in the diet can be largely prevented if weaned infants and children get suitable supplementary foods of high nutritive value at a low cost.

Need for Processed Protein Food Supplements

The long term plans for increased production of protective foods will take a good deal of time to yield the desired results. In view of the acute shortage in the supply of milk and other protective foods, there is an urgent need for developing protein-rich processed food supplements from readily available raw materials. Fortunately, there are abundant supplies of protein-rich foods of vegetable origin such as oilseed meals which have not so far been used as articles of human food. During recent years considerable amount of work has been carried out by several workers in different countries on the utilisation of oilseed meals for human consumption. It is possible to convert these oilseed meals into highly nutritious food supplements by suitable processing and fortification with vitamins.

Availability of Raw Materials

In the processing of a supplementary food on a commercial scale, important considerations have to be based on the supply of raw materials. In the first place, these must be produced in the country on a large scale. These must also be procurable with comparative ease and at low cost. Due consideration has also to be placed on the acceptability of the different constituents composing the food.

India produces large quantities of edible oilseeds and nuts and the meals obtained from some of these are quite rich in proteins. Of these, groundnut meal is available in large quantities. Sesame meal and cocoanut meals are available only in limited amounts[6]. Pulses are also important sources of protein in the Indian dietary. Among these Bengalgram is available in large quantities. The figures for the annual production of certain oilseeds and nuts and Bengalgram during 1954-55 are given in Table I.

Table I

Name of material	Production for 1954–55 (tons)
Groundnut (in shell) ...	3,823,000*
Sesame seeds ...	592,000
Copra ...	185,000
Bengalgram (whole pulse) ...	5,125,000†

* The approximate annual production of the meal will be about one million tons.

† The production figures for Bengalgram is given in the above table as it has been used in the supplementary food.

Whole groundnut kernel is being used in a variety of preparations to a limited extent all over the country and as such people are used to the characteristic taste and flavour of groundnut. Low fat groundnut flour has an attractive creamy colour and a pleasant nutty flavour and the consumers generally show a liking to such flours[7]. Sesame meal is somewhat less rich in proteins but its proteins are rich in the essential amino acid—methionine[8], in which the groundnut protein is deficient; but sesame meal has a slight bitter taste and as such can be incorporated only in limited amounts in processed food preparations.

Cocoanut meal is a fair source of protein of high biological value but its high fibre content restricts its use as a sole protein supplement to the diet[9]. Soyabean meal is rich in proteins of high biological value and hence will be a very valuable constituent of protein foods. At present, this legume is not grown on a large scale in India and it is desirable to increase its production. Further, investigations are necessary to explore the possibilities of utilising other oilseed meals, such as sunflower, safflower, cottonseed etc. for incorporation in processed foods suitable for human consumption.

Chemical Composition of Pulses and Oilseed Meals

The chemical composition of some edible oilseed meals as well as certain legumes and skim milk powder which have been suggested as possible supplements to human dietaries is given in Table II.

It is evident from the above table that all the oilseed meals with the exception of cocoanut meal are very rich sources of protein. They are also good sources of certain vitamins of the B-complex. Cocoanut meal is only a fair source of protein (20.9 per cent), and it has a high fibre content (10.5 per cent) which restricts its use as a sole protein supplement to the diet. It will be noted that the oilseed meals are deficient in calcium (with the possible exception of sesame meal), riboflavin and vitamins A and D in which the diets consumed commonly by the children of low income groups are lacking.

Amino Acid Composition of Oilseed Meals

The essential amino acid make up of the proteins of oilseed meals as compared to that of Bengalgram, certain cereals and skim milk powder is given in Table III.

It is evident from the table that the proteins of different oilseed meals vary to a significant extent in their essential amino acid composition. Groundnut proteins are deficient in methionine and lysine. Sesame proteins are rich in methionine, while proteins of Bengalgram are rich in lysine. Cocoanut proteins are fairly rich in all the essential amino acids. The limiting amino acids in the groundnut meal can be made up by sesame meal, Bengalgram and cocoanut meal proteins. So, by suitably blending the different foods, it is possible to get a protein mix which will be fairly complete in essential amino acids and which will have a fairly high biological value.

Supplementary Value of Proteins of Oilseeds and Pulses to those of Cereals

Vegetable proteins in general are less nutritive than animal proteins. This is due to the fact that the former are deficient in one or more of the essential amino acids. It has been observed by a large number of workers that the proteins of oilseeds, pulses and cereals supplement each other, so that it is possible by mixing different vegetable proteins to get a blend of high nutritive value.

Pulse proteins, especially those of Bengalgram are rich in lysine and have been reported to have a significant supplementary value to the proteins of rice and *ragi*[10]. Phansalkar *et al.*[11] reported that a blend of pulse protein (3 per cent) and cereal proteins (7 per cent) had a higher protein efficiency ratio than cereal proteins alone (10 per cent). The proteins of Bengalgram were found to supplement markedly those of wheat, parboiled wheat and *jowar*[12]. Johns and Finks[13], Eddy and Eckmann[14] and Jones and Divine[15] showed that the addition of 10-25 per cent of groundnut meal to wheat flour considerably enhanced the nutritive value of wheat flour proteins. Smuts and Marais[16] observed that proteins of

TABLE II. *Chemical composition of low fat groundnut flour as compared with certain other protein rich foods*

Description of materials	Moisture %	Protein (N×6.25) %	Ether extractives %	Carbohydrates %	Crude fibre %	Ash %	Calcium %	Phosphorus %	Iron (mg) %	Thiamine (mg) %	Nicotinic acid (mg) %	Riboflavin (mg) %
Soyabean flour (low fat) ...	5.0	50.0	7.0	31.0	2.5	5.5	0.33	0.62	20.0	0.70	5.7	0.58
Groundnut flour (low fat) ...	11.0	52.7	8.9	21.8	1.0	4.6	0.07	0.50	2.9	0.95	19.5	0.20
Sesame flour (low fat) ...	5.6	33.2	12.2	38.1	4.8	6.0	2.38	0.63	19.3	1.05	5.3	...
Cottonseed flour (alcohol extracted)	9.2	52.1	5.5	25.8	1.5	5.9	0.36	0.82	12.0	0.99	...	...
Cocoanut flour (low fat) ...	11.2	20.9	13.3	39.2	10.5	4.9	0.16	0.49	5.7	0.17	4.1	...
Bengal gram flour ...	11.2	22.5	5.2	58.9	...	2.2	0.07	0.31	8.7	0.45	...	...
Skim milk powder ...	4.1	35.0	1.0	51.0	...	6.8	1.30	0.03	0.6	0.35	1.1	1.39

TABLE III. *Amino acid composition of groundnut proteins as compared with the proteins of some other common foodstuffs*

(Calculated at 16.0g. of nitrogen)

Amino acids (g.)	Rice	Wheat	Jowar	Bengal gram	Soyabean flour	Groundnut flour	Sesame flour	Cottonseed flour	Cocoanut flour	Whole milk protein
Arginine ...	7.2	4.3	...	6.9	7.3	11.3	8.7	11.3	10.8	4.2
Histidine ...	1.7	2.1	1.6	2.3	2.9	2.1	1.5	2.7	2.41	2.6
Lysine ...	3.2	2.7	3.4	6.4	6.8	3.0	2.8	3.5	5.80	8·6
Tryptophane ...	1.3	1.2	1.22	0.6	1.4	1.0	1.8	1.3	...	1.5
Phenylalanine ...	5.0	5.1	5.1	5.0	5.3	5.1	8.0	6.0	4.0	5.5
Methionine ...	3.0	2.5	1.7	1.7	1.7	1.0	3.2	1.7	2.0	3.2
Threonine ...	3.8	3.8	...	4.8	3.9	1.6	4.0	3.0	...	4.7
Leucine ...	8.2	7.0	12.95	8.0	8.0	6.7	7.5	6·0	7·3	11.0
Iso-leucine ...	5.2	4.0	6.09	6.0	6.0	4.6	4.8	5.3	5.3	7.5
Valine ...	6.4	4 3	5.91	5.4	5.3	4.4	5.1	5.3	5.3	7.0

groundnut flour possessed a good supplementary value to those of oat meal. Sure[17] reported that groundnut proteins supplemented those of maize to a significant extent. Rama Rao *et al.*[18] reported that the proteins of groundnut supplemented adequately those of *bajra* (*Pennesetum typhoideum*). Supplementary relationships have also been observed between groundnut proteins on the one hand, and oat proteins, corn proteins and rice proteins on the other[19]. Groundnut proteins were found to be inferior to those of skim milk at 10 per cent level of protein intake but at 20 per cent level of intake the proteins of groundnut were almost equal to the proteins of skim milk in promoting the growth of rats[20]. Thus in the case of groundnut, the lower nutritive value of the proteins could be compensated by a higher intake of proteins. Sesame proteins are rich in tryptophane and methionine[8]. As such, it is a valuable supplement to vegetable proteins which are normally deficient in these amino acids. The proteins of sesame were found to supplement those of groundnut and the mixed proteins of groundnut and Bengalgram[21].

Being rich in lysine and valine, soyabean proteins supplement those of wheat and other cereals and compare favourably with milk proteins in this respect[22]. The proteins of soyabean were

also found to supplement those of yellow corn and rye[23]. Dean[24] observed that soyabean and cereal malts in suitable proportions could form a combination almost equal in nutritive value to milk proteins in child feeding. Cottonseed proteins are deficient in lysine and to a lesser extent in methionine and cystine. Jones and Divine[15] have shown that cottonseed proteins significantly supplement those of wheat.

The literature cited above would indicate that by suitable blending of oilseed meals with pulse flours it is possible to get a protein mixture of high biological value, which will supplement cereal proteins to a significant extent.

Requirements of Processed Vegetable Protein Foods

During recent years considerable amount of work has been carried out in different countries on the utilisation of plant foods in child feeding[5,24]. In planning vegetable protein mixtures for supplementing human diets, it is necessary to take into consideration the following factors: (1) the amino acid content of the individual ingredients and the final product; (2) the possible presence of toxic or interfering factors; (3) the need for obtaining exact specifications for each of the components; (4) the necessity of avoiding processes that damage the quality of the protein; (5) the desirability of using products of local origin; (6) the low cost and good keeping quality of the product; (7) the suitability of the product for feeding weaned infants and (8) the acceptability of the product to the consumers. The products should not be recommended for commercial production until the products are found satisfactory by the following tests: (1) freedom from toxicity as tested by animal experiments; (2) moderately high biological value of its proteins as assessed by animal growth studies; (3) demonstration of the supplementary value and acceptability of the product to the diet of children under careful medical supervision and (4) large scale feeding trials in selected population groups to assess its general acceptability. Although the primary objective is to provide a supplementary source of protein of good quality, it is desirable that a vegetable protein mixture *should also contain adequate quantities of vitamins and minerals that are likely to be lacking in the diets of the low income groups of the population.* This can be achieved by fortification with minerals and synthetic vitamins which are available in large quantities at low cost.

Investigations on Processed Protein Foods in India

Very few investigations have so far been made in processing protein-rich foods fortified with vitamins and minerals. Barsook[25] developed a highly nutritious food known as multipurpose food using soya grits. Harris *et al.*[26] developed a soup powder from low fat groundnut flour, low fat soyaflour, cooked pea flour and skim milk powder with added flavours and condiments as also essential amino acids and minerals. Subrahmanyan *et al.*[27] prepared a balanced food in the form of broken vermicelli using maize starch, groundnut flour, casein and dried yeast and fortifying the product with vitamins and minerals.

Balanced Food

Lal and De[28] developed a balanced food in the form of broken vermicelli from a blend of groundnut, soyabean, wheat and tapioca flours together with dried yeast, common salt and condiments. Feeding trials carried out on young albino rats indicated that the food was well balanced and that it had a good supplementary value to a poor South Indian diet.

Lal and Rajagopalan[29] extended the above investigation and processed a balanced food using groundnut, sesame and soyabean flours together with wheat and tapioca flours and fortified the product with vitamins and minerals. The composition of the food is given in Table IV. The

TABLE IV: *Chemical composition of the 'Balanced Food'*

Moisture % ...	3.1
Protein (N × 6.25) % ...	34.8
Mineral matter % ...	5.9
Crude fibre % ...	2.5
Carbohydrate % ...	53.6
Calcium (mg.) % ...	353.0
Phosphorus (mg.) % ...	453.1
Iron (mg.) % ...	5.3
Thiamine (B_1) (mg.) % ...	0.22
Riboflavin (B_2) (mg.) % ...	0.25
Nicotinic acid (mg.) % ...	7.14
Vitamin A and carotene (I.U.) % ...	140.5

food was made in the form of broken vermicelli and was found to cook like rice.

These workers assessed the biological value of the proteins of the food by the growth method, nitrogen balance technique, haemopoietic value, and regeneration of liver proteins[30]. The results of these studies showed that the proteins of the food were of fairly high biological value. The usefulness of the food was further investigated by studying the supplementary value of the food to poor cereal diets, the effect of feeding the food as the entire ration on reproduction and lactation in rats, the availability of B-complex vitamins and the extent of availability of calcium and phosphorus. Feeding trials with children of age ranging from 4 to 10 years were also conducted. The comparison in this case was against the American multipurpose food. The data gave convincing proof of the value of the food as a source of good quality proteins, vitamins and minerals. The nutritional status of the subjects under study, as determined by height, weight, R.B.C., haemoglobin, serum albumin and excretion of the vitamins in urine, was almost the same as those receiving the American MPF and was significantly better than those receiving the normal food of the convent where the experiments were conducted.

Indian Multipurpose Food (Indian MPF)

Subrahmanyan *et al.*[31] standardised a method for the production of Indian MPF made out of a blend of 75 parts of specially processed groundnut flour and 25 parts of Bengalgram flour fortified with vitamins and minerals. The food was made in three forms, *viz.*, *seasoned*, *unseasoned* and *unseasoned with added skim milk solids*. The chemical composition of the food as compared with that of American multipurpose food and skim milk powder is given in Table V.

Kuppuswamy *et al.*[32] and Joseph *et al.*[33] reported that Indian MPF at 12.5 per cent level had a significant supplementary value to poor vegetarian diets based on different cereals and millets and in this respect was comparable to that of American MPF. The same workers also reported that the proteins of Indian MPF were of fairly high biological value, though slightly lower than that of American MPF[34]. The proteins of Indian

TABLE V. *The chemical composition of Indian and American multipurpose foods as compared with skim milk powder (values per 100 g)*

Constituent	Indian multipurpose food	Skim milk powder	American multipurpose food
Moisture (g.) ...	6.8	4.1	6.7
Protein (N × 6.25) g. ...	41.9	35.0	42.3
Fat (g.) ...	8.5	1.0	7.6
Ash (g.) ...	7.0	6.8	6.5
Carbohydrate (by diff.) g. ...	35.8	51.0	36.9
Calcium (g.) ...	0.665	1.30	0.587
Phosphorus (g.) ...	0.820	1.03	0.440
Iron (mg.) ...	5.1	0.6	7.0
Thiamine (mg.) ...	1.3	0.35	0.7
Nicotinic acid (mg.) ...	14.0	1.1	7.0
Riboflavin (mg.) ...	3.0	1.39	1.2
Vitamin A (I.U.) ...	3000	Trace	2940
,, D (I.U.) ...	300	nil	235
Calorific value ...	387	353	386

MPF were found to significantly supplement those of poor rice diet[34].

Joseph *et al.*[35] studied the relative value of the proteins of Indian MPF, Bengalgram (*Cicer arietinum*) and skimmed milk powder in meeting the protein requirements of protein depleted rats. Three groups of protein depleted rats were fed on diets (14 per cent protein) containing multipurpose food, Bengalgram and skim milk powder for a period of 21 days. The animals fed on skim milk powder retained greater amounts of nitrogen than those fed on multipurpose food or Bengalgram. The ability of the different foods to meet the protein requirements of protein depleted rats ranged in the following descending order: skim milk powder, multipurpose food and Bengalgram.

Feeding studies with children were carried out in a boarding home in Mysore to assess the effect of supplementing their diet daily with 2 ounces of Indian MPF on their growth and nutritional status[36]. Forty-six girls of age ranging from 4 to 12 years were divided into two similar groups. One group received daily a supplement of 2 oz. of multipurpose food given in the form of soup or chutney. The other group continued to receive the usual diet and served as control. In order to equalise the calorie intake, the control

group received daily 1 oz. of sugar and 1 oz. of starch in the form of pudding. At the end of the feeding period of 5 months, height, weight, Red blood cell count and haemoglobin content of blood of the children were determined and their nutritional status assessed. The data are presented in Table VI.

TABLE VI. *Increase in height, weight, haemoglobin and R.B.C. count of control and experimental children*

(23 children in each group)

	Control (Rice diet)	Experimental (Rice + MPF) diet	Significance of difference
Height (inches) ...	0.52	0.96	Sig. at 1%
Weight (pounds) ...	1.00	2.61	„ 0.1%
Haemoglobin (g/100cc) ...	0.13	1.00	„ 5%
Red blood cell (10^6/cu.mm)	0·07	0.33	„ 1%

The results convincingly showed that supplementation of the diet with multipurpose food produced a marked improvement in weight, height, R.B.C. count and haemoglobin of the experimental children. Metabolism studies carried out during the feeding trial showed that the children receiving the MPF supplement retained significantly larger amounts of nitrogen, calcium and phosphorus than the control children who did not receive the supplement[37].

Subrahmanyan *et al.*[38] reported that Indian MPF with added skim milk solids was very effective in the treatment of *Kwashiorkor* in children. The subjects (children aged 2-3 years) suffering from *Kwashiorkor* were administered Indian MPF with added skim milk solids, the daily dose being 4-5 oz. per child. The product was given in divided doses, four times a day, as gruel sweetened with sugar. A marked improvement in the general condition of the subjects was observed within 8-10 days. Oedema began to subside from the 5th to 7th day and completely disappeared in about 3 weeks. Diarrhoea completely stopped at about this time. Dermatosis and hyperpigmentation began to heal by about the 10th day and was completely cured in 20-25 days. Analysis of the serum of subjects before and after treatment showed that there was a definite increase in the total serum protein and albumin of the subjects. The results are given in Table VII.

TABLE VII. *Biochemical findings in cases of nutritional oedema syndrome before and after treatment with low cost protein food*

Constituents of blood	Name of patients					
	J		G		P	
	Initial	Final	Initial	Final	Initial	Final
Haemoglobin (g/100cc blood)	9.42	11.60	6.95	9.42	9.28	10.87
Red blood cell count (10^6/cmm. blood) ...	3.00	4.20	2.90	3.75	2.98	3.60
Serum:						
Total protein% ...	3.69	7.01	3.52	6.83	3.53	7.20
Albumin% ...	1.55	4.01	1.53	3.81	1.39	4.03
Globulin% ...	2.14	3.00	1.99	3.02	2.14	3.17
Non-protein nitrogen ...	0.02	0.021	0.018	0.019	0.019	0.021

The photograph of one of the subjects before and after treatment is shown in Fig. I.

In addition to the investigations reported above, a large number of field and clinical studies were also carried out. The clinical studies were conducted at different centres of the country as a part of a programme of research work under the auspices of the Indian Council of Medical Research. The reports from these centres confirmed in a large measure the earlier findings, *viz.*, that the processed protein food (Indian multipurpose food) was effective in the prevention and treatment of protein malnutrition.

Processed Protein Foods containing Cocoanut Meal

Cocoanut meal is available in large quantities as a by-product of the oil industries in certain parts of India, especially in the Kerala State. Cocoanut meal though not rich in protein as compared

FIG. I. **Patient on admission showing oedema of the legs and hands and skin changes (crazy pavement and hyperpigmented areas)**

FIG. II. **Same patient completely cured after treatment for 6 weeks with low cost protein food.**

to other oilseed meals is a good source of all essential amino acids. The proteins have a biological value higher than that of other oilseed proteins. The high fibre content of cocoanut meal, however, precludes its use as a sole protein supplement to the diet. Krishnamurthy *et al.*[39] prepared a composite protein food from a blend of cocoanut meal, low fat groundnut flour and Bengalgram flour fortified with different vitamins and minerals. The chemical composition of the protein food containing cocoanut meal is given in Table VIII.

Tasker *et al.*[40] reported that the protein food when incorporated at 12.5 per cent level had a significant supplementary value to a poor vegetarian diet based on rice. The same workers also reported that the proteins of the above food were of fairly high biological value and in this respect superior to either groundnut or Bengalgram[40].

Subrahmanyan *et al.*[41] carried out institution feeding trials to study the effect of a daily supplement of 2 oz. of protein food containing cocoanut meal on the growth and nutritional status of the children. The results are given in Table IX.

TABLE VIII. *Chemical composition of the protein food containing cocoanut meal*

Moisture	8.8%
Protein	36.5%
Fat	7.6%
Crude fibre	3.0%
Ash	4.7%
Carbohydrates (by diff.)	39.4%
Phosphorus	0.65%
Calcium...	0.48%
Vitamins in 100 g. of protein food	
Vitamin A (I.U.)	3,000
,, D (I.U.)	300
Thiamine (mg.)	1.4
Riboflavin (mg.)	3.1

Statistical analysis of the results showed a significant improvement in the height, weight, R.B.C. count and haemoglobin level of the subjects receiving the supplement of protein food over those in the control group. Metabolism

TABLE IX. *Increase in height, haemoglobin and R.B.C. count of control and experimental children*
(20 boys in each group)

	Control (Rice diet)	Experimental (Rice + protein food diet)	Significance of difference
Height (inches) ...	1.27	1.61	Sig. at 1%
Weight (pounds) ...	1.25	3.31	,, 0.1%
Hæmoglobin (g/100cc) ...	–0.08	0.69	,, 5%
Red blood cell (10^6/cu.mm) ...	–0.08	0.22	,, 1%

studies carried out during the feeding studies showed that the children receiving the protein food supplement retained significantly larger amounts of nitrogen, calcium and phosphorus than the control children who did not receive the supplement[42].

Conclusions

It is evident from the foregoing account that besides cereals and pulses which form important sources of protein in the diet of the low income groups in tropical countries, oilseeds and oilseed meals represent an abundant and a most important source of proteins which have not been fully utilised so far for supplementing human diets. In view of the acute shortage in the supply of milk and other protective foods, the problem of providing low cost balanced protein supplements utilising oilseeds and oilseed meals for combating malnutrition in under-developed countries has been engaging the attention of scientists in several countries. FAO and UNICEF are also aiding governments through their regular and technical assistance programme in the production of low cost food supplements utilising oilseeds and oilseed meals. There is a need for further investigations to discover new combinations and preparations of local foods, which can be used for feeding infants and children. There is no doubt that increased production and consumption of processed protein foods based on oilseed meals and pulses and fortified adequately with synthetic vitamins, at a cost lower than that of natural protective foods, will play a very important role in improving the diet and nutritional status of the majority of the population in India and other technically under-developed countries.

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STUDIES ON INFANT AND INVALID FOODS BASED ON MILK

By V. Subrahmanyan, M. R. Chandrasekhara, M. Narayana Rao and M. Swaminathan
(Central Food Technological Research Institute, Mysore)

Infant and invalid foods based on milk have been manufactured in large quantities in Europe and America for the past several years[1,2]. The important foods belonging to the above category are: (1) Dried milk foods (2) Malted milk beverages and (3) Composite protein foods based on casein for use as supplement to the diets of invalids and convalescents. These products have so far been imported into India and only recently a beginning has been made in the manufacture of milk powder in the country[3]. A good deal of work has been done in Western countries on the choice of equipment and on the standardisation of conditions for the production of these foods from cow's milk[1,2]. Most of these processes have remained as trade secrets. Until recently, no attempts have been made in India either to standardise the conditions for the production of the above category of foods from cow's milk or to study the suitability of buffalo milk which is available in large quantities, for the preparation of these products. During the last five years investigations have been carried out at the Central Food Technological Research Institute, Mysore on the production of infant and invalid foods using buffalo milk. A brief account of these investigations is given in the present review.

Import of Infant and Invalid Foods

India has been importing large quantities of infant and invalid foods, sweetened condensed milk and milk powder, and casein foods[4]. An approximate estimate and value of the imports during 1954-55 are given in Table I. It will

TABLE I. *Imports of milk products including infant and invalid foods into India (1954–55)*

Item	Quantity (tons)	Value (in million rupees)
Butter ...	613	3.80
Cheese ...	464	1.9
Patent Foods:		
Milk food for infants and invalids ...	2,646	12.45
Other sorts ...	1,625	6.83
Evaporated and condensed milk:		
Whole (including cream) ...	4,227	9.99
Skimmed ...	587	0.71
Dried milk:		
Whole milk powder ...	1,200	3.92
Skim milk powder ...	27,206	28.49
Total value ...		68.13

be observed that the total value of the annual imports of infant and invalid foods and milk products amount to about 68 million rupees.

The quantity of liquid milk required for manufacturing the various products imported during the year 1954-55 will be about 330 thousand metric tons.

Milk production in India

India ranks third in the world, in the matter of liquid milk production[5]. The annual production in 1954 amounted to about 19 million and 318 thousand tons; but in view of the large population, the *per capita* daily availability of milk is only about 5 ounces. The major milk producing regions in India are shown in Table II.

TABLE II. *Production of cow and buffalo milk in major milk producing areas in India (1945)*

	Cow's milk	Buffalo's milk	*Per capita* daily milk production (ounces)
	(in 1,000 metric tons)		
Bihar ...	799	771	4.4
East Punjab ...	676	1,400	16.9
Uttar Pradesh	1,500	2,460	7.2
Baroda ...	36	346	13.6
Rajasthan ...	403	234	15.7
Sourashtra ...	223	410	18.8
Total ...	3,637	5,621	

It is evident that the important regions having surplus milk production are Sourashtra, Punjab Baroda, Rajasthan, Uttar Pradesh and Bihar. Kaira district in Bombay State is producing large quantities of buffalo milk and is supplying milk to Bombay city. It is also of interest to note that these regions produce more of buffalo milk than cow's milk. Cow's milk is mostly being utilised as such for feeding infants and children and as a supplement to the diet of adults, while buffalo milk is being used for the preparation of butter, *ghee* and curds. In the above regions only a surplus of buffalo milk is available. As mentioned earlier the quantity of buffalo milk (330 thousand tons per annum) required for the production of dairy products imported at present (vide Table I) can be easily collected from Sourashtra, Kaira district, Punjab, Uttar Pradesh and Bihar. This will represent only about 1.5 per cent of the milk produced in the country and about 10 per cent of the milk production in the above regions.

Composition of Buffalo milk as compared with Cow's milk

The average composition of the milks of some breeds of Indian cows and buffalos[6] as compared with that of the milks of cows of European breeds is given in Table III.

TABLE III. *Average composition of milk of cow and buffalo*

Constituents	Indian cow	Indian buffalo	European cow
Water ...	35.28	81.74	87.40
Total solids ...	14.72	18.26	12.60
Solids-not-fat ...	9.05 ?	10.15	8.93
Fat ...	5.67	8.11	3.67
Proteins ...	3.60	4.33	3.42
Lactose ...	4.69	5.00	4.78
Ash ...	0.76	0.82	0.73

It will be seen that the average fat content of the Indian cow's milk is distinctly higher than that of the European breeds of cow. The average fat content of Indian buffalo milk is about *twice* that of the European cow's milk. It is evident that buffalo milk has a definite advantage economically over cow's milk as a raw material for the manufacture of infant and invalid foods and milk powder, as large amounts of butter fat obtained as a by-product will help to bring down the cost of production of the different products.

Studies on the Production of Spray dried and Roller dried Infant Foods from Buffalo milk

The two methods commonly employed for the preparation of milk powder and infant foods are: (1) roller or drum drying and (2) spray drying. Roller drying has the following advantages over spray drying: (*i*) the relatively lower initial cost of the equipment, (*ii*) space-saving compactness, (*iii*) suitability to regions of moderate milk production (10-20 thousand pounds per day) and (*iv*) better keeping quality of the powder. The only disadvantage of roller drying is that the solubility of roller dried milk powder in cold water is slightly less than that of the spray dried product, but this

TABLE IV. *The composition of some infant foods*

Product	Fat %	Protein %	Carbohydrate %	Mineral salts %	Moisture %	Description
Spray dried infant food* ...	14.0	22.0	56.0	5.0	3.0	Spray dried partially skimmed buffalo milk modified by the addition of sucrose.
Roller dried infant food* ...	14.0	23.0	55.7	4.7	2.4	Roller dried partially skimmed buffalo milk modified by the addition of sucrose.
Glaxo ...	26.5	24.9	38.5	5.6	5.9	Dried cow's milk (unmodified).
Cow and Gate (Full cream food) ...	27.3	26.6	37.6	6.0	2.5	A standardised unmodified milk food suitable for feeding normal children up to 9 months.
Cow and Gate (Half cream food) ...	15.0	20.0	58.0	4.5	2.5	A milk food with reduced fat for children up to 3 months and older fat intolerant infants.
Lactogen ...	25.0	16.2	53.3	3.5	3.5	Dried milk food modified by the addition of lactose.

* Standardised at the Central Food Technological Research Institute, Mysore (India).

is not a serious drawback as infant foods are usually reconstituted in hot water. Further there are only very few areas in India where sufficient milk (40-50 thousand pounds per day) is available for feeding a spray drier. On the other hand there are several areas in India where the availability of milk per day is about 10-20 thousand pounds and where the roller driers can be economically worked. In view of the above, it will be desirable to set up more number of roller driers in different regions of the country having surplus milk production.

Investigations were conducted at the Central Food Technological Research Institute, Mysore for standardising the conditions for the production of infant foods by both the roller and spray drying processes[7-14]. The following aspects of the problem have been studied: (1) Studies on the curd tension of buffalo milk and standardisation of the formula for infant food (2) Studies on the shelf life of the products and (3) Feeding trials on infants.

Studies on the Curd tension of Buffalo milk and Standardisation of the Formula for Infant Food

The curd tension of the reconstituted milk from the infant food should be low to enable the infant to digest the food easily. The investigations carried out by Chandrasekhara *et al.*[7] showed that even though the curd tension of raw buffalo milk was higher than that of raw cow's milk, boiling and addition of phosphates and citrates (which react with ionised calcium) brought about a marked reduction in the curd tension of the milk. The curd tension of the reconstituted milk from the infant food prepared from buffalo milk was quite low (3.5) as compared with that of the infant foods prepared from cow's milk. The composition of buffalo milk was so modified that after drying, an infant food with a protein content of 20-22 per cent and fat content of 14-15 per cent was obtained. As infant food having this composition will be more suitable for infants in the tropics in view of the fact that the protein and fat requirements of children under tropical conditions are somewhat lower than the standards suggested for temperate climates. The lowering of the fat content to about 14 per cent will facilitate easy digestion of the food by infants, as majority of infants in India experience difficulty in the digestion of fat. The composition of spray dried and roller dried infant foods prepared from buffalo milk as compared to that of some proprietory infant foods available in the market is given in Table IV.

Large scale Production of Spray dried Infant Food

A large scale preparation of the spray dried infant food was undertaken at the factory of the Kaira District Co-operative Milk Producers'

Union Ltd., Anand using a commercial model Niro spray drier[10]. For obtaining infant food of good quality the following precautions were taken: (*i*) the milk was collected under hygienic conditions, thus keeping the bacterial contamination at a minimum and (*ii*) contamination of the milk with copper was kept at a minimum by tinning the brass vessels used for milking. A flow sheet of the process of manufacture of spray dried infant food from buffalo milk is given in Fig. I. The process consisted of the following steps: (1) Pasteurization (2) Reduction of fat content of buffalo milk to 2.5 per cent (3) Addition of cane sugar to adjust the protein content of the final product to 24 per cent and the fat content to 14 per cent (4) Addition of buffer salts (5) Concentration (6) Addition of vitamins to the concentrated milk (7) Homogenization (8) Spray drying and (9) Packing in containers under nitrogen. The infant food was packed under nitrogen in 1 lb. tin containers provided with tagger tops and lever lids and used for the feeding trials.

FIG. I. *Flow sheet for the production of spray dried infant food.*

Raw buffalo milk
|
Collection and quality control
|
Pasteurization
|
Partial skimming — Cream
| |
Standardization of fat in milk to 2.5% Butter—Packing
| |
Addition of buffer salts and sugar *Ghee*—Packing
|
Concentration
|
Addition of vitamins
|
Homogenization
|
Preheating
|
Spray drying
|
Packing in containers under nitrogen
|
Spray dried infant food

Large scale Production of Roller dried Infant Food

The large scale manufacture of roller dried infant food was carried out at the factory of Messrs Healthways Ltd., Varanasi. The flow sheet of the process is shown in Fig. II. The process consisted of the following steps: (1) Pasteurization (2) Reduction of fat content of buffalo milk to 2.5 per cent (3) Addition of cane sugar to adjust the protein content of the final product to 22-24 per cent and the fat content to 14-16 per cent (4) Addition of buffer salts and vitamins (5) Homogenization (6) Drying and (7) Powdering and packing. The roller dried infant food was packed in air in one lb. tins provided with tagger tops and lever lids.

The ex-factory cost of production of the foods have been worked out by Chandrasekhara *et al.*[15,16] and comes to about Rs 2 per lb.

FIG. II. *Flow sheet for the production of roller dried infant food from buffalo milk.*

Raw buffalo milk
|
Collection and quality control
|
Pasteurization
|
Partial skimming — Cream
| |
Standardization of fat in milk to 2.5% Butter—Packing
| |
| *Ghee*—Packing
Addition of buffer salts, sugar and vitamins
|
Homogenization
|
Preheating
|
Roller drying
|
Disintegration
|
Packing
|
Roller dried infant food

Shelf life of Spray dried and Roller dried Infant Foods

Chandrasekhara *et al.*[9] studied the shelf life of spray dried infant food prepared from buffalo milk stored under air and nitrogen. The spray dried infant food when packed under nitrogen had a shelf life of 8 months at 37°C and 16 months at 27°C. When packed in air, it had a shelf life of 3.5 months at 37°C and 8.0 months at 27°C. The same workers[13] studied the shelf life of roller dried infant food prepared from buffalo milk packed under air. The results showed that the roller dried food had a shelf life of about 10 months at 37°C and an expected life of 20 months at 27°C. It is evident

TABLE V. *The increase in weight of infants fed on spray and roller dried infant foods*

Name of Centre	Number of infants	Age of infants (Range)	Duration of feeding (Range months)	Average increase in weight per month (lb)
Spray dried infant food				
Mysore ...	52	9 days–11.5 months	1–5	0.83
Delhi ...	10	27 ,, 2½ ,,	1–2	1.60
Calcutta ...	22	1 month–24 ,,	0.5–4	2.00
Roller dried infant food				
Mysore ...	20	1½ months–10 ,,	3½	0.88

from the results that under similar conditions of storage, roller dried infant food has a longer shelf life than spray dried food.

Infant feeding Trials with Spray dried and Roller dried Infant Foods

Feeding trials on infants (Table V) carried out in different centres[11, 14, 17] have shown that both the spray dried and roller dried infant foods are readily digested by infants. The average growth and health of the infants fed on the two infant foods were quite satisfactory comparing well with those of Indian infants fed on cow's milk and/or other proprietory infant foods.

Malted Milk Products

Malted milk products were being produced in large quantities in Europe and America. The two most important products belonging to the above category are: (1) Malted milk powder and (2) Malted milk beverage flavoured with cocoa. The high nutritive value and pleasing flavour of the products are mainly responsible for their wide popularity. Malted milk powder is mostly used as a food for invalids and convalescents while milk beverage flavoured with cocoa is being used widely as a substitute for coffee, tea, etc., by invalids and convalescents.

India has been importing large quantities of the above type of products. Till recently, no attempt was made to standardise the conditions for their production in the country. Investigations were therefore undertaken in the Central Food Technological Research Institute, Mysore, to standardise the conditions for their production. The process[18,19] developed by the workers of the Institute is briefly described below:

Preparation of Malted milk powder

The process consists of the following steps: (1) Preparation of *ragi* or barley malt (2) Mashing of the malt with gelatinised wheat flour, filtration and concentration of the malt extract (3) Blending of malt extract with partially skimmed buffalo milk and fortification with vitamins (4) Drying of the product under vacuum and (5) Powdering and packing. The flow sheet of the process is shown in Fig. III.

FIG. III. *Flow sheet for the production of Malted milk powder.*

Raw buffalo milk—Receipt and testing—Pasteurization

Cream separation——Cream

Malt Extract—Partially skimmed milk   Ripening of cream

Concentration   Butter—Packing

Vitamins—Concentrated milk   *Ghee*—Packing

Homogenization

Dehydration

Powdering

Packing

Malted milk powder

Composition

The composition of malted milk powder as compared with that of Horlicks, which is a well known brand of malted milk powder available in the market is given in Table VI. It is evident that the protein and fat content of the food developed in the Institute are of the same order as those of Horlicks.

TABLE VI. *Percentage chemical composition of Malted milk powder*

Constituent	Malted milk powder	Horlicks
Moisture ...	5.9	4.6
Protein (N×6.25) ...	13.0	13.4
Fat ...	8.5	7.9
Ash ...	5.0	3.2
Carbohydrate (by diff.)	67.6	70.9
Calcium ...	0.91	0.69
Phosphorus ...	0.48	0.38
Thiamine (mg) ...	0.37	0.40

TABLE VII. *Percentage chemical composition of malted milk powder flavoured with cocoa*

Constituent	Malted milk powder with cocoa	Ovaltine
Moisture ...	3.0	2.5
Protein (N×6.25) ...	13.8	14.2
Fat ...	7.8	8.0
Ash ...	3.6	3.5
Carbohydrate (by diff)	71.8	71.8
Calcium ...	0.65	0.60
Phosphorus ...	0.48	0.45

Preparation of Malted milk Beverage flavoured with Cocoa

The process consists of the following steps: (1) Preparation of *ragi* or barley malt (2) Mashing of the malt with gelatinised wheat flour, filtration and concentration of the malt extract (3) Blending of the malt extract with partially skimmed buffalo milk, cocoa and vitamins (4) Drying of the product under vacuum and (5) Granulating and packing.

The flow sheet of the process is given in Fig. IV.

FIG. IV. *Flow sheet for the production of Malted milk powder with cocoa.*

Raw buffalo milk — Receipt and testing — Pasteurization
Cream separation — Cream
Sugar, Malt extract, Cocoa, Caramel
Partially skimmed milk | Ripening of cream
Concentration | Butter—Packing
Concentrated milk | *Ghee*—Packing
Homogenization
Dehydration
Granulation
Packing
Malted milk powder with cocoa

Composition

The chemical composition of the product is given in Table VII. The protein and fat contents of the beverage food developed in the Institute are of the same order as those of Ovaltine, which is a well-known brand of malted milk beverage available in the market.

Nutritionally balanced Malt Food

The object in developing malt foods is to provide a cheap food supplement to weaning infants and children of parents belonging to the low income group and who cannot afford to buy milk and milk powder. It could be easily prepared in large quantities from readily available raw materials. Investigations carried out by Chick and Slack[20] and Dean[21] have shown that a highly nutritious food can be prepared by blending barley malt with soya bean. Dean[21] reported that about half the milk in the diet of infants up to an age of one year can be replaced by a barley malt-soya mixture and even more so in the diet of older children. He also found that there was scarcely any difference in the growth of children given a milk supplement and those receiving the malt-soya mixture containing 10 per cent skim milk powder.

A process for the preparation of a nutritionally balanced low cost malt food has been developed recently at the Central Food Technological Research Institute, Mysore. The product consists of a blend of cereal malt, low fat groundnut flour, roasted pulse flour, skim milk powder and sugar. It is also fortified with essential vitamins and minerals.

The flow sheet of the process is shown in Fig. V.

The composition of the product as compared to whole milk powder is given in Table VIII. Animal experiments have shown that the malt food when incorporated at 10 per cent level in poor rice diet has a supplementary value comparable to that produced by the same level of whole milk powder[23]. The malt food when cooked in about 8 parts of water, yields a

Fig. V. *Flow sheet for the production of Nutritionally balanced malt foods.*

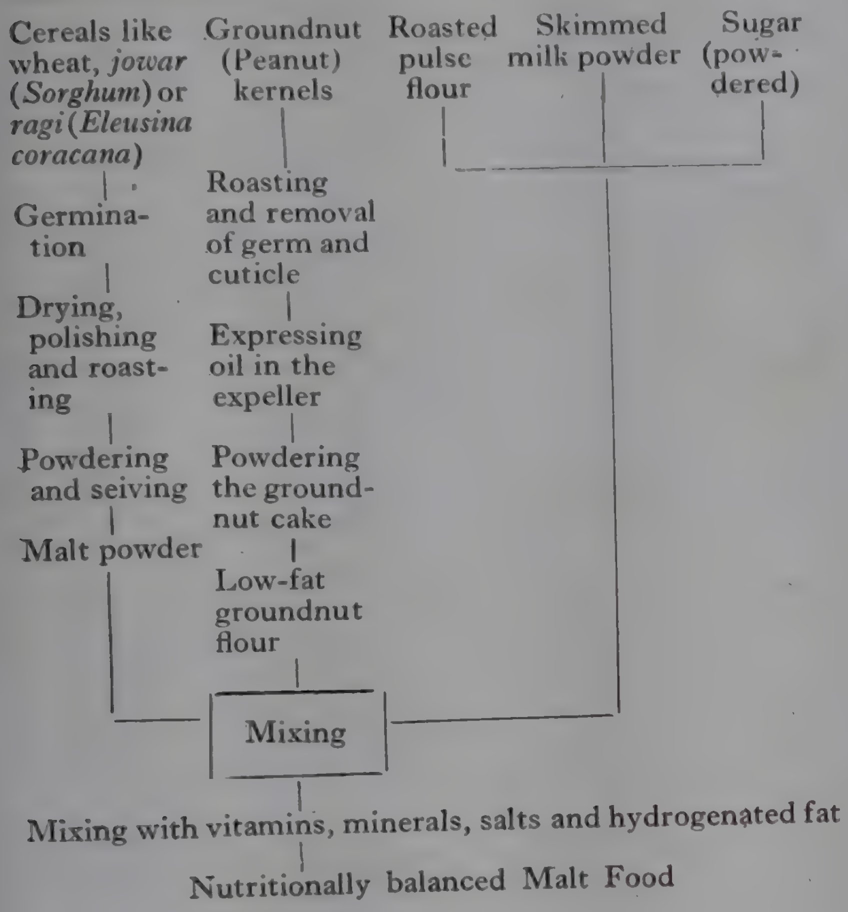

Table VIII. *Percentage chemical composition of low cost malt food*

Constituent	Low cost malt food	Whole milk powder
Moisture ...	3.8	3.5
Protein (N×6.25) ...	24.2	24.6
Fat ...	6.2	30.0
Ash ...	5.8	5.7
Carbohydrate (by diff.) ...	60.0	36.2
Calcium ...	1.16	0.90
Phosphorus ...	0.86	0.69
Iron (mg.) ...	2.12	0.60
Vitamin A (I.U.) ...	5000	1570
,, D (I.U) ...	400	8–160
Thiamine (mg.) ...	1.52	0.29
Riboflavin (mg.) ...	1.58	1.39
Nicotinic acid (mg.) ...	10.6	0.7

highly nutritious porridge with a pleasant taste. A supplement of 2 ounces of the product will provide most of the nutrients lacking in poor Indian diets of weaned infants belonging to the low income groups of the population.

Composite Protein Food

Composite protein foods mainly based on casein are intended to be used as a supplement to the diet of invalids, convalescents, growing children, expectant and nursing mothers. A process for the preparation of a composite protein food has been developed recently at the Central Food Technological Research Institute[24], Mysore. The process consists of converting casein into a solubalised form by treatment with certain alkaline salts under specified conditions and fortification with different vitamins and minerals. The composition of the product is given in Table IX. The

Table IX. *Chemical composition of composite protein food*

Constituent	Values per ounce
Protein (N×6.25) g. ...	22.4
Calcium (as Ca) g. ...	0.166
Phosphorus (as P) g. ...	0.304
Thiamine (mg.) ...	2.9
Riboflavin (mg.) ...	2.9
Calcium pantothenate (mg.) ...	2.9
Pyridoxine (mg.) ...	2.9
Folic acid (mg.) ...	0.9
Nicotinic acid (mg.) ...	11.4

product contains a large percentage (80 per cent) of proteins of high biological value. In addition to this, it contains calcium and glycerophosphate in easily assimilable form. It is very easily digested and utilized by the body and hence is specially indicated during convalescence, pregnancy, lactation and other debilitating diseases when the need for easily assimilable proteins, vitamins and minerals is increased. Feeding experiments carried out on school children showed that supplementation of the diet with one ounce of composite protein food daily, for a period of two months, produced a remarkable improvement in the growth and general health of the children[25]. The composite protein food was found to be very effective in the treatment of protein malnutrition (*Kwashiorkor*)[26]. The children suffering from *Kwashiorkor* were given daily 1½ oz. of composite protein food mixed in water and sweetened with sugar. A marked improvement in the general condition of the patients was observed within a week. Oedema subsided even on the 5th day of treatment and completely disappeared in about

3 weeks. Diarrhoea stopped in about a week. The dermatosis and hyperpigmentation began to disappear from the second week of treatment and all the subjects were discharged after 3 weeks of treatment. Analysis of the serum of the subjects before and after treatment has shown a definite increase in the total serum proteins and serum albumin.

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SOME UNFAMILIAR FOODS—THEIR PROCESSING AND NUTRITIONAL VALUE

By M. V. L. Rao, M. Srinivasan and V. Subrahmanyan

(*Central Food Technological Research Institute, Mysore*)

India's vast floral wealth holds immense potentialities for newer food sources. To this the hundreds of foods mentioned in the pages of that *magnum opus*, Watt's 'Dictionary of the Economic Products of India' bears sufficient testimony. Some of these have been occasionally tapped in times of scarcity. Others have remained largely unknown. There are also food materials which are grown and consumed in particular regions. In the past, the exploitation of all these potential food sources have been rather sporadic as spurred on by the exigencies of the food situation. Mounting and chronic food shortages in recent years have led to a renewal of interest in exploring newer food sources and systematically investigating the less familiar foods from the standpoint of processing and nutritional evaluation as human foods.

Broadly speaking, the term 'unfamiliar foods' would include entirely new and the less known natural foods as well as new processed products derived through technological applications. This article will, however, deal mainly with the natural categories and such of the processed products as are not treated elsewhere in these reviews. Fundamental findings of interest from the nutritional and biochemical angles will also be indicated.

Newer sources of Starch and other Polysaccharides

Roots and tubers have been traditional alternatives to cereals as sources of starch in times of acute shortage. The immense potentialities for growing cassava or tapioca as an alternative food crop, the processing of the tapioca starch into useful and highly nutritious rice-like grains as substitutes for the major cereals are discussed elsewhere in this brochure.

A hitherto unexpected source of starch was discovered in the banana stem by Subrahmanyan and co-workers[1]. The stem yields 4-5 per cent starch. The method of processing the stem has been worked out and possible uses for the starch indicated. The digestibility of the starch is comparable with that of maize starch[2].

The kernel of the tamarind seed has been well known as a famine food. Chemical studies by Savur and Sreenivasan[3] indicated that the seed contained a peculiar polysaccharide which was not a true pectin and biological studies by Bose *et al.*[4] demonstrated clearly that it was not utilised in the animal body. Further examination of the polysaccharide has shown that it is a polyose containing galactose, xylose and glucose in the proportion 1:2:3[5,6]. It has also been shown that it is a good substitute for fruit pectins for making jams, jellies and marmalades and also for starch as a textile sizing substitute[38a].

The stem of the agave (*Agave vera cruz* Mill.) is another famine food. The soft woody portion of the stem is cooked with tamarind and *jaggery* and consumed by the poorer classes under famine conditions. Investigations by Srinivasan and co-workers[7,8] indicated that the stem contained as the storage carbohydrate, a polyfructosan which in physical and chemical characteristics was different from inulin occurring in Jerusalem artichoke, hitherto, the only natural source of commercial fructose. The fructosan is easily cleaved by acid hydrolysis to fructose, a sugar nearly twice as sweet as cane sugar. Conditions have been standardised for preparing fructose syrup from the agave stem and its commercial potentialities indicated[9].

Experimental investigations have shown that the carbohydrates as present in the original stem are not well utilized in the animal body[10,11]. Cooking in the traditional way and throwing away the water leads to loss of assimilable carbohydrates released by the hydrolysis in the acidic medium. Even if the cooking water is retained, the material could be ingested only to a limited extent on account of certain deleterious constituents[11,12]. But it could be included in small proportions in mixed diets as a non-leafy vegetable with beneficial results as it contains useful amounts of calcium[12].

Fundamental studies on the agave polyfructosans have shown that the bio-synthesis of the fructosan is mediated by a transfructosidase and that sucrose is its main precursor[13]. More recently the polyfructosan has been subjected to structural

analysis by Aspinall and Das Gupta[14] at the Chemistry Department in the University of Edinburgh. It has been shown that the agave polyfructosan is a highly branched polysaccharide in which both 2:1 and 2:6 linked β-D-fructofuranose residues occur, D-glucose residues being present solely as non-reducing end-groups. Onion and garlic are other sources of similar polyfructosans but these have not been structurally characterised[8a, 43a].

Arvi or colocasia (*Colocasia antiquorum*) is a tuber rich in starch and containing fair amounts of protein. Jain, Das and Lal[15] standardised a procedure for drying the tuber and preparing a flour out of it which could be incorporated to the extent of 50 per cent in wheat flour for making *chapatis*. Ramachandran and Phansalkar[16] have determined the amino acid composition of the proteins in this tuber.

Some little known Cereals, Millets and Cereal Substitutes

Among the lesser known cereals which have been recently studied, the price of place goes to the seeds of *rajgira* (*Amaranthus paniculatus* L.) used as a minor cereal in the states of Bombay and Uttar Pradesh where it is cultivated as a minor mixed crop. It is also said to grow wild in the Himalayan regions and is reported to be a staple food of certain hill tribes. In experimental plot studies at the Central Food Technological Research Institute, Mysore, yields of the order of 500 lb. per acre have been obtained. The main virtue of the seed lies in its high protein content coupled with easily digestible carbohydrate component. The growth promoting value of the seeds is three times as much as that of rice. Puffing is the best method of processing the seeds for human consumption. The puffed material has an agreeable flavour and taste and has considerable possibilities as a breakfast cereal[17].

The seed of the bamboo, popularly called bamboo rice, enjoys great reputation among the accredited famine foods as having saved the lives of thousands in lean years in the past. Flowering only once in its life span of 15-20 years, the bamboo is reported to yield very large quantities of seeds during the season. The husked seeds resemble rice but they have a thicker and tougher bran coat which is difficult to polish completely. The fully or partially polished grains cook like rice but are more glutinous. The grains can be cooked and consumed the same way as rice or as various culinary preparations made out of the flour. The grains contain about 12 per cent protein of high biological value and are superior in overall nutritive value to rice[18].

Millets have served as valuable subsidiary foods in tiding over the acute shortage of major cereals. In recent years, a number of minor millets have been studied with respect to their nutritive value *per se* and as substitutes for the common cereals. Rama Rao, Murthy and Swaminathan[19] studied the nutritive value of pearl millet, one of the important millets grown in India, as a source of protein, B-vitamins and minerals and as a staple food in a poor vegetarian diet. It was superior to wheat. They have also found that the protein efficiency ratio of *bajra* proteins was higher than that of wheat proteins and that the proteins of Bengal gram and groundnut significantly supplemented those of *bajra*. Sur, Swaminathan and Subrahmanyan[20] studied the nutritive value of *jowar* as a substitute for wheat and found that in growth promoting value it was inferior to whole wheat. Kadkol, Sreenivasamurthy and Swaminathan[21] studied the nutritive value of another minor millet, *haraka* (*Paspalum scrobiculatum*) and this was found to be inferior in its overall nutritive value to wheat. Supplementary value of the millet to rice diets has been studied by Kundaji and Radhakrishna Rao[22]. The nutritive value of little millet (*Panicum miliare*) was investigated by Kadkol *et al.*[23] It was found to possess an overall nutritive value lower than that of wheat. Chitre and Ganapathi[24] found that the proteins of Italian millet (*Setaria italica*) lack essential amino acids like lysine and tryptophan and possesses no growth promoting value. But Ganapathi *et al.*[25], observed that proteins of cow pea and horse gram satisfactorily supplemented the proteins of Italian millet.

The water chestnut (*Trapa bispinosa*) is another satisfactory cereal substitute which was investigated by Subrahmanyan *et al.*[26] It is poor in protein but the growth promoting value of the protein is high. The nut is superior to rice in overall nutritive value[27].

Protein Rich Sources

Oilseed cakes: Oilseeds are generally potent sources of protein also. The residual cakes obtained after extraction of the oil have been explored as human food. The use of judicious blends of such cakes in the preparation of a high-protein multipurpose food containing a nutritionally well-proportioned assortment of essential amino acids is described in another context in this brochure. Among the less investigated oilseed cakes, cottonseed and poppy seed cakes have been examined recently from the nutritional point of view. Subrahmanyan *et al.*[28] and Krishnamurthy *et al.*[28a] observed a marked supplementary value of an alcohol-extracted, low fat cottonseed flour to diets based on *ragi* and *jowar* and a moderate supplementation to rice and wheat diets, as determined by the rat growth method. Sathyanarayana *et al.*[29] have found that the proteins of oil-free poppy seed meal possess a moderate biological value and a fair make-up of essential amino acids. The usefulness of these cakes for enrichment of human foods has yet to be ascertained.

Vegetable milks: The preparation of protein and fat-rich emulsions from oilseeds simulating cow's milk have been known for quite some time. In certain countries like China, cow's milk is reported to have been largely replaced by soyabean milk. In India, pioneering work in the field of vegetable milks was carried out by scientific workers at the Indian Institute of Science, Bangalore and was further extended at the Central Food Technological Research Institute, Mysore. These extensive studies have established the feasibility of preparing milks and derived products from soya bean and other indigenous oilseeds such as groundnut and their value in the nutrition of toddlers, growing children and adults and also in the treatment of several types of protein malnutrition (Hunger oedema, *marasmus Kwashiorkor*, etc.). All aspects of the subject are thoroughly discussed in a monograph on 'Milk substitutes of vegetable origin'[30]. On the whole, conversion to milk appears to be the best way of ingesting fair amounts of the oilseed components and deriving the maximum nutritional benefit especially from the protein.

Legumes: Pulses or legumes are important sources of dietary protein particularly for the vegetarian. Tamarind seed and sesbania seed are among the less common legumes recently investigated. Bose and Subramanian[31] found that the proteins of the tamarind seed had a protein efficiency ratio of 1.53 in rat growth tests. The proteins of the seeds of *Sesbania grandiflora* Pers. have been investigated in detail by Subramanian *et al.*[32] The seeds are remarkably rich in protein containing as much as 70 per cent. But the biological value of these proteins is of a very low order. This has been traced to their extremely low content of methionine (less than 0.5 per cent). Deshpande and Radhakrishna Rao[33,34] found that the proteins of aconite bean (*Phaseolus aconitifolius*) have a biological value of the order of 50-55, methionine again being the limiting amino acid.

Leaves: As the most dynamic of plant organs, leaves are endowed with a high compliment of proteins. Their utilization for the preparation of protein concentrates for human consumption has been mooted from time to time. Pioneering work in this field has been done in recent years by Pirie and associates at Rothamsted, and Slade and his group at the I.C.I. in England and by a few American workers. The rather unattractive flavour and colour of the products obtained, their high fibre content and cost of production militate against a more widespread exploitation of leaves as protein-rich sources. The preparation of an acceptable product with low fibre content at moderate cost is a bio-engineering problem still awaiting solution.

In India, the first attempts at preparing proteins from leaves in a form fit for human consumption were made by Guha and associates[35,36] during the Bengal famine in 1943. Subsequently, they have made an extensive study of the protein content of a variety of leaves and of the possible processing methods. These investigations have served to locate some protein-rich leaves, such as those of groundnut and sesbania[37], and provided basic information which would be of great value in developing practical processing techniques in the future. Bose and Bhattacharya[38] have developed an elegant procedure for the extraction of chlorophyll from leaf extracts.

Apart from a large moiety of protein, leaves also contain other proximate principles which considerably add to their nutritional value especially as supplements to certain practical diets of poor quality. Lucerne or alfalfa (*Medicago sativa*) leaf is a prominent instance in point. Sur and Subrahmanyan[39,40] found that even at low levels (4 per cent) of incorporation lucerne leaf flour exhibited a phenomenal supplementary value to the poor rice diet in respect of growth. Certain other leaves also show a similar effect but at much higher levels[56]. The high calcium content of the leaves appears to be majorly involved in this effect. Anandaswamy and Date[41] have worked out a processing method for obtaining a fibre-free lucerne concentrate rich in protein, minerals and vitamins in both liquid and tablet form. Such concentrates could be incorporated in high proportions into dehydrated soup powders and other foods, and markedly supplement the growth promoting value of poor rice diets.

In analysing eight different kinds of leafy vegetables consumed in South India, Theophilus and Arulanatham[42] located three high protein sources (35-39 per cent on the dry basis), *viz.*, *mukarattai* (*Boerhavia repens*), *kuppameni* (*Acalypha indica*) and *nerringi* (*Tribulus terrestris*). Sathyanarayana and Rama Rao[43] analysed a newly introduced leafy vegetable, *Sauropus androgynus* (L) Merr. (Chakur manis) for proximate principles and amino acid content. The leaves were found to contain high amounts of protein with a fair complement of essential amino acids.

Deshpande and Radhakrishna Rao[33,34] found that the proteins of amaranth leaves (*Amaranthus gangeticus*) have a biological value of 67 and a good supplementary value to a poor rice diet. The leaf protein is rich in lysine, leucine and valine. Even at low levels, marked supplementary relationships have also been found between the proteins of amaranth and those of *bajra*, wheat, *jowar* and Bengal gram[44]. On the basis of these encouraging results, the hope has been expressed that it may be possible to obtain through judicious admixture of vegetable sources, protein mixtures comparable in biological value to milk proteins.

Yeasts: Food yeast provides an excellent instance of a concentrated protein and vitamin-rich food produced by agriculture-independent means from simple chemical substances and also industrial wastes or bye-products. During the last world war, *Torula* yeast was produced by a commercial firm in India and sold at Rs 1/8 per lb. On account of its peculiar flavour, bitter taste and high cost compared with other vegetable protein sources such as soya bean or groundnut flour, it did not become popular. The firm was therefore obliged to discontinue production. Unless food yeast could be produced and sold at competitively low rates, the prospects for it as human food do not appear to be bright[45].

However, some interesting nutritional results have been reported. Sur *et al.*[46,47] have shown that food yeast makes a good supplement to poor vegetarian diets based on *ragi* and milo, and a moderate one to those based on rice. The proteins of food yeast markedly supplement the proteins of *jowar*, *ragi* and wheat but only moderately those of rice.

Miscellaneous: Siddappa and Bhatia[48] have studied the composition and uses of jack fruit seeds. The seed contains mainly starch with a fair amount of protein. The flour prepared by milling the seed has been found to make *chapatis* satisfactorily when mixed with wheat flour up to 25 per cent. Siddappa[49] also found a powerful trypsin inhibitor in the seeds which could be destroyed by autoclaving at 10 psi for 30 minutes by boiling in water or salt solution and by baking.

Bains *et al.*[50] examined the seeds of *Caesalpinia pulcherrima* L. with a view to utilizing the edible mucilage in it and have shown conclusively that the mucilage is a galacto-mannan polysaccharide. The cotyledon is rich in protein, oil and phosphorus. In nutritional studies[51] with albino rats, the mucilage has been found not to affect either the digestibility of the protein, carbohydrate and fat or the growth promoting value of test diets containing 1.5—3.0 per cent of the mucilage. From the chromatographic picture of the faecal carbohydrates, evidence has been adduced to support the inference that the mucilage is digested by the rat.

The jelly-like kernels of the tender palmyra palm (*Borassus fabellifer*) eaten by people in India during hot season to quench thirst and cool the human system, has been investigated by Subrahmanyan *et al.*[52] with regard to the nature

of the carbohydrate components. The main polysaccharide was found to be a galactomannan. The presence of an insoluble fibrous material of the mannose-cellulose type of polysaccharide complex was indicated.

'Shathi food' manufactured from the rhizome (*Curcuma zedoaria*) has been analysed by Kadkol[53]. It was found to be primarily a starchy food whose *in vitro* digestibility by salivary amylase is comparable with that of maize starch.

Moorjani[54] has analysed the lotus rhizome (*Nelumbium speciosum* Willd.) commonly growing in lakes and ponds in India. It is mainly composed of starch but contains a fair amount of protein.

Befri seed (*Indigofera glandulosa*) another alleged famine food was investigated by Bose and Subramanian[31]. It has 30 per cent protein with a protein efficiency ratio of one.

In investigations on minor food materials carried out in the Department of Nutrition of the Government of Bombay, a few minor oilseeds rich in riboflavin and a new and fairly rich source of vitamin C have been located[55].

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PLACE OF SPICES AND AROMATICS IN INDIAN DIETARY

By V. Sreenivasamurthy and K. Krishnamurthy

(Central Food Technological Research Institute, Mysore)

Seasoning of foods is an age old practice and it is intended mainly to improve the palatability of the foodstuffs. The primary quality that is looked for in a food product by the consumers is its organoleptic quality rather than its nutritive value. Consequently, even a highly nutritious food is not accepted if it is not adequately spiced. Thus spices play a very important part in our dietary in making foods palatable and acceptable. Besides this, spices possess certain additional qualities which make them indispensable in our diets and which deserve serious attention.

Physiological action of Spices

The condiments do not contribute much to the food value measured in terms of carbohydrates and proteins. They may increase the vitamin content of the foodstuffs to some extent; but, this is negligible, when compared to the amount of vitamins supplied by other components of the diet. The most important contribution of the spices to our dietary is to improve the organoleptic quality of food products and this has a direct bearing on the food consumption. Krishnamurthy *et al.*[1] have recorded increases in food consumption in rats as a result of supplementing the diets with tamarind, salt and chilly. With the increased food consumption, the amount of different nutrients ingested will also increase. Further, most of the salt used in Indian diets carries appreciable quantities of calcium[2]. Consumption of more salt increases the supply of calcium to the body with the consequent improvement in the nutritional status in respect of calcium requirements. Likewise, even in human beings, seasoning of foods enhances food consumption followed by increases in the amounts of nutrients ingested.

The process of digestion and assimilation of the ingested food is a complex phenomenon. It includes the secretions of a variety of enzymes. The secretions of each of these components of the digestive juices, particularly of salivary and gastric juice, are either stimulated or inhibited by a number of factors. Among these factors, sense of smell is the most important one. The classical experiments of Pavlov[3] have clearly demonstrated the control exerted by the nervous system over different secretions of the alimentary tract. Secretions of the salivary and gastric glands are largely dependent on the psychic states of man. Salivary and gastric secretions are increased when the nerve centres are stimulated by the sense of smell[3a] and by the presence of certain irritating substances in foods. Spices, by the pleasant aroma they impart to the foodstuffs and by the

TABLE I. *Medicinal Properties of Spices*

Anthelmintics	Carminatives	Laxatives	Diuretics	Flatulence preventives	Dyspepsia preventives
Turmeric Garlic Asafœtida Coriander	Asafœtida Aniseed Coriander Caraway Ginger Cardamom Nutmeg Fenugreek	Turmeric Asafœtida Coriander	Garlic Aniseed Coriander Cardamom Fenugreek	Garlic Asafœtida Ajowan Ginger	Turmeric Asafœtida Ajowan Ginger

presence of irritating compounds contained in some of them, stimulate the secretions of digestive juices in large quantities and thereby improve digestion and assimilation of the ingested food. Colouring by saffron and turmeric improves the 'eye-appeal' of the foodstuffs and has similar beneficial effects on secretions.

In recent years, attention has been focused on the effect of some of the spices commonly used in India on the activities of the digestive enzymes. Bhatt and associates[4] found that asafoetida had no significant effect on the activities of the salivary amylase, pepsin, trypsin, renin, pancreatic amylase and pancreatic lipase. Likewise, it had no effect on intestinal enzymes[5]. Bhatt and co-workers[6] reported that saffron and nutmeg stimulated the activities of pepsin and renin. Thus, it is evident that spices promote digestion by increasing secretions of the digestive juices and at least some of them by stimulating the enzymic activities. However, excessive seasoning of food, as practised in some parts of India, is reported to be injurious to health as excessive gastric secretions may lead to gastritis[7]. In moderate amounts, they are definitely useful.

Medicinal properties of Spices

In the Indian system of medicine, spices and aromatics have a vital role to play. They are reputed to possess many medicinal properties and hence they are the inevitable ingredients in most of the indigenous medicines. Kirthikar and Basu[8], and Nadkarni[9] have described the medicinal properties of Indian medicinal plants and the information available on the spices that are commonly used has been summarised in Table I. Some of them are good carminatives, some are diuretics and others are useful in colic diseases and in preventing flatulence.

For maintenance of good health, normal functioning of our body machinery, particularly of secretary and excretory functions, is necessary. Influence of spices and aromatics on the secretions of the alimentary system has been referred to earlier. According to the information available (Table I), they are also carminatives, laxatives, diuretics, etc. and seem to influence the excretory functions as well. Thus, it is evident that spices tend to influence both the secretary and excretory functions of our body and thereby seem to aid in the maintenance of a better state of health. Consumption of pepper water, ginger juice, garlic preparations, etc., as part of the daily menu is a some popular remedy practised in Indian homes, in the treatment of many of the alimentary disorders.

Antibacterial activity of Spices

Although the medicinal properties of spices have been recognised since ages long, there is practically no information on the mechanism of their action in exerting medicinal effects. Some workers believe that the beneficial effect of spices is due to the essential oils present in them. Because of the fact that some of the spices are administered in preventing flatulence, studies on the effect of spices on the growth and activity of the micro-organisms inhabiting the intestinal tract were carried out by a number of workers[10, 11]. This aspect of study has been dealt with, in greater detail, in the following pages under individual spices. In general, it can be stated that some of the spices possess strong antibacterial substances and are helpful in suppressing the abnormal increase in the number of micro-organisms in the

TABLE II. *Principle Constituents of Spices*

Sl. No.	Material	Principle constituents
1	Garlic (*Allium sativum*)	Allin 0.4% and other diallysulphides.
2	Asafœtida (*Ferula fœtida*)	Resin 40-60%, gum 25% and volatile oil 10%.
3	Pepper (*Piper nigrum*)	Piperine 5-0%, volatile oil 1-2·5% consisting chiefly of phellandrene.
4	Ajowan (*Trachyspermum ammi*)	Volatile oil 4-6% consisting of 45-55% thymol.
5	Cloves (*Syzygium aromatum*)	Volatile oil 15-20% consisting of 85-92% eugenol.
6	Turmeric (*Curcuma longa*)	Curcumin, volatile oil 5-6%
7	Cardamom (*Elettaria cardamom*)	Volatile oil 3-8% (terpene and terpineol).
8	Ginger (*Zingiber officianale*)	Volatile oil 1-3% consisting chiefly of camphene and phellandrene.
9	Chillies (*Capsicum*)	Capsaicin 0.2-1.0%.
10	Cinnamon (*Cinnamum Zeylanicum*)	Volatile oil 0.5-1.0% consisting of 42-75% cinnamic aldehyde.
11	Aniseed (*Pimpinella anisum*)	Volatile oil 1.5-3.5% consisting of 84-87% anethole.
12	Cumin (*Cuminim cyminum*)	Volatile oil 2.5-4% consisting of 35-62% cumaldehyde.
13	Coriander (*Coriander sativum*)	Volatile oil 0.2-1.0% consisting of 50% linalol.
14	Caraway (*Carum carvi*)	Volatile oil 0.4-1.0% consisting of 50-60% carvone.
15	Saffron (*Crocus sativus*)	Volatile oil safranel.

intestinal tract. Subrahmanyan *et al.*[11] have studied the effect of different diets on the microflora inhabiting the intestines and observed that high red gram *dhal* diet promotes the growth of large numbers of anaerobic bacteria in the intestines. Presence of roughage in the diet, as in diets containing *ragi*, favours the growth of both coliform and anaerobic bacteria on larger numbers[12]. These workers[13] have found that inclusion of garlic in the diet markedly reduces the counts of different types of micro-organisms.

Chemical and other Important Properties of Different Spices

Spices are composed of various parts of a large number of different plants. They consist, in general, volatile and non-volatile oils, protein, fibre, starch, mineral matter, tannins, etc. The flavouring and characteristic properties of many spices are due to the presence of volatile oils. In many cases, the characteristic flavour is not due to one single component but due to a mixture of different components—alcohols, esters phenols and resins. Table II shows the principal components of different spices.

Garlic: Garlic is widely cultivated all over the world and used both as a spice and a popular remedy for many ailments[14]. It has antiseptic, diaphoretic, diuretic and expectorant properties and is being widely used in Ayurvedic system of medicine[15].

Cavallito *et al.*[16] have shown that allicin is the antibacterial principle of garlic. Allicin is formed as a result of enzymatic degradation of a larger molecule called allin by an enzyme, allinase. In the case of enzymatic cleavage of allin, a typical odour and taste of garlic appears which is due to allicin in the beginning and finally to diallyl sulphide. Stoll and Seebeck[17] synthesised allin by careful oxidation of desoxy allin. Raghunandan Rao *et al.*[18] described a modified method for the isolation of allicin from garlic. Datta and co-workers[19] isolated two active fractions from garlic and called them allisatin I and II.

Subrahmanyan *et al.*[11] compared the antibacterial activity of the water extracts of commonly used spices and condiments on the growth of bacteria inhabiting these intestines. They reported that garlic was found to be the most potent spice exhibiting high antibacterial action on *E.coli*, *A. aerogenes*, *M. aureus* and *S. sonnei*. They also studied[20] the relative susceptibilities of different organisms towards water-extract of garlic and reported that concentrations of garlic required to inhibit *L. casei* and *S. faecalis* are much higher than those required to inhibit *E.coli*, *S. sonnei* and *M.aureus*. The same authors[21] also studied the effect of incorporation of garlic extract in the diet on the intestinal microflora of rats. They reported that the bacterial counts of both ceca and faeces of rats fed on the stock diet rich in roughage and on the red gram *dhal* supplemented poor rice diet, and administration

of garlic, at therapeutic levels, along with the diet brought down considerably the number of coliforms, total aerobic and anaerobic bacterial counts.

Satoh[22] reported that there was an increase in the intestinal synthesis of thiamine on administration of garlic in human subjects. Hides Terado[23] studied the *in vitro* synthesis of thiamine from garlic oil by *E. coli*. Watanabe[24] and Yurugi[25] carried out investigations on thiamine derivatives and found that alli-thiamine was formed by the reaction of thiamine and allicin. It was also reported that alli-thiamine was absorbed at a faster rate than thiamine in the intestines. Toxicity tests on mice indicated that LD_{5}, for allicin in aqueous solution to be of the order of 60 mg./kg. intravenously and 120 mg./kg. by subcutaneous administration.

Asafoetida: Asafoetida is a gum resin derived chiefly from an umbelliferous plant (*Ferula foetida*) and is obtained as an exudation of the decapitated rhizome or root of the plant[26]. Asafoetida is regarded as a spice and is widely used in the different dishes. It is also used in medicine as a carminative and antispasmodic, as an expectorant and in preventing flatulence. Mixed with pepper and sweet flag, it is a popular medicine in the house holds[15, 26].

The chief constituents of asafoetida[26] are resin, gums, volatile oil and traces of umbelliferone. The resin consists of asaresino-tannol both free and combined with ferulic acid. Asafoetida owes its strong characteristic odour to the oil present in it which is a mixture of different sulphides, hexynyl sulphide, hexynyl disulphide allyl sulphide and terpenes.

Bhatt, *et al*[4]. reported that asafoetida had no bacteriostatic effect on some of the common intestinal micro-organisms and that it altered the proportion of hydrogen and carbon dioxide formed by the gas-formers in the intestines. Sreenivasamurthy and Sastry[27] reported that asafoetida oil, like an antibiotic, inhibits the growth of organisms and under the influence of the asafoetida oil, *S. faecalis* assumed giant sizes possibly due to an interference with cell division and not growth. The same authors reported[27] that both coliforms and anaerobes are much lower in number in the ceca of albino rats fed asafoetida oil than those in the control.

Turmeric: This is the orange yellow powder obtained from the boiled and dried rhizome of the plant *Curcuma longa*. This is used in the dietary as a colouring agent. This contains a colouring matter called curcumin. Ramprasad and Sirsi[28] have shown that curcumin has antibacterial activity. Turmeric is reputed to be a good carminative, laxative and an anthelmintic.

Ajowan: The seeds of *Trachispermum ammi* which are popularly known as ajowan or *omum* are used in the dietary and in the household medicines. They contain thymol which has been reported by Bose *et al.*[29, 30] to possess antiseptic properties. Its anthelmintic property is well known and it is used in the treatment of flatulence, indigestion, etc. It is used mainly in savoury dishes where pulses form the major constituents.

Aniseed: The seeds of *Pimpinella anisum* popularly known as aniseed contains an essential oil, rich in anethole. It is known to be stimulant, carminative and also a diuretic. Sreenivasamurthy and Krishnamurthy[31] studied the effect of water extract of aniseed on the growth of some bacteria and found that it stimulated the growth and acid production of *L.Casei*.

Coriander: The seeds of *Coriandrum sativum* are used in the Indian dietary almost in every savoury dish. It is reported[9] to be a stimulant, carminative and also a diuretic. Its strong fragrance acts as an appetiser.

Ginger: The rhizomes of *Zingiber officianale* are used either in raw state or after drying. It is known to be a good stimulant and a carminative[9].

Saffron: The dried stigma of the flowers of *Crocus sativus* is used for both flavouring and colouring sweet dishes. It is reported[32] to be a stimulant, aphrodisiac and a stomachic. In over-doses, it acts as a narcotic poison.

Cardamoms: The dried ripe seeds of *Elettaria cardamomum* possess a strong smell and are used as a flavouring agent in most of the sweet dishes. This is also reputed[9] to act as a stimulant, carminative and also a diuretic.

Pepper: The dried unripe fruits of *Piper nigrum* are used mostly in savoury dishes for their

delicate aroma and biting quality. Besides, the dry fruits are also reported to act as a carminative. Water extract of pepper is a popular household medicine commonly used in Indian homes in the treatment of alimentary disorders.

Essential oils: The essential oils are the volatile components of various spices and plants. They are chemically different from one other, even though they are all flavouring substances.

The germicidal property of essential oils has been known for a long time and has been estimated by different workers. Bose *et al.*[29, 30] studied the relationship between the chemical constitution of the constituents of certain essential oils and their bactericidal properties. They reported that aldehyde groups have been found to be generally more active than the hydroxyl groups. The presence of a double bond in terpene aldehydes and alcohols enhances the efficiency of the active group. The same authors[29, 30] reported that lemon grass oil was the most effective one. Notable reduction in germicidal activity was observed in the presence of faeces, serum and milk.

Conclusions

The foregoing will show that most of the spices that are being used in the Indian dietary are reported to possess different physiological and medicinal properties. There is very little information available on the mechanism of their action. Some of them have been found to be antibacterial. This obviously suggests that they may exert their beneficial effect by suppressing the growth of harmful intestinal bacteria. But, considering the quantity of the spices consumed, the medicinal effects they exert on the human system seems to be out of proportion to their anti-bacterial properties. It appears, therefore, that there is an alternate mechanism of action by which the spices act as therapeutic agents. Investigations are in progress at this Institute to explore this aspect.

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SOME INDIGENOUS SPICES AND TASTE ADJUNCTS

By M. Srinivasan, T. N. Ramachandra Rao and L. V. L. Sastry
(*Central Food Technological Research Institute, Mysore*)

Spices are used to a considerable extent the world over as flavouring agents, but their ancestral home has been India. Pioneer voyages to this country were made in quest of this natural wealth. Because of their economic importance, some of the major spices like asafoetida, garlic, ginger, pepper, saffron and turmeric have come in for much attention in recent times at the hands of scientists in the country. In furtherence of these studies, a vapour-phase chromatographic equipment has now been acquired by the Central Food Technological Research Institute, Mysore.

Asafoetida

Asafoetida is used in Europe mostly as a drug and in India mostly as a spice, all of it being imported. Asafoetida is the dried latex from the cut surface of certain species of *Ferulas* (N.O. Umbelliferae) occurring in Eastern Iran and parts of Afghanistan. As the fresh latex is caustic to the skin, calcareous materials are added to it to facilitate handling. A plant yields 2-3 lb. of the crude material. Asafoetida is an oleo-gum-resin, the odour components being a ferulic ester and a sulphur-containing volatile oil. Habitat, cultural conditions, details of collection and chemistry are reviewed by Subrahmanyan and Srinivasan[1].

Analytical data for authentic samples are presented by Subrahmanyan *et al*[2]. The two recognised types of asafoetida are the *Hing* and *Hingra*. Depending on the country of origin (Iran or Afghanistan), the Hings are referred to as Irani Hing or Pathani Hing. Imports of Hing are made under accepted trade names of which at least nine enter India. They are Gulmin, Hadda, Kabulidana, Khada, Khawal, Nayachal, Nayazamin, Ras and Shabandi. Sastry *et al*.[3] examined representative samples of each of these from the bulk imports and showed that these varieties differed considerably in physical appearance, in the strength and quality of odour and in overall analysis. Hadda has maximum odour and is most priced. Kabulidana and Shabandi are considered lower in quality and are priced cheap, the cheapest being Hingra.

According to trade practice, the imported varieties, either individually or mixtures of them, are blended in varying proportions with gum, starch etc., and then sold as Bandhani Hing. Estimation of alcohol solubles, total ash, organic sulphur, carbohydrates, gums, resins, volatiles and fibre showed[4] that, in the sample marked 'compounded', the alcohol solubles were much less than the specified limit of ten per cent. In some of the samples not so marked, though the alcohol solubles were more than ten per cent, the ash content, however, was much higher than the specified limit of ten per cent. Thus, none of the samples tested satisfied the presumptive standards. This has been confirmed by others[5,6,7] working with market samples obtaining in their regions. Nor, according to Sastry[8], is organic sulphur a criterion of purity.

Even where a sample satisfies the standards, there is no guarantee that it is genuine asafoetida, or that it is of good quality. For example, cheap varieties like Kabulidana and Shabandi have higher alcohol solubles and also higher sulphur content than costlier varieties[8]. On the basis of certain colour reactions, however, it is possible to base a classification which roughly tallies with tariff classification based on price structure[3]. As there is no objective measure yet for odour, it was of interest to determine, even approximately the minimum quantity of asafoetida which would give a blend of acceptable quality. For this purpose, Sastry[4] prepared small lots by uniformly compounding varying proportions of different brands of asafoetida gums and wheat flour. Gum karaya was found to facilitate quick setting of the product to a hard mass. The final product containing only 25 per cent Kabulidana or Shabandi —both cheap varieties—was undistinguishable in physical appearance, organoleptic quality and analysis from the best market sample of compounded asafoetida. This shows how difficult it is to assess the true quality of a natural flavouring material like asafoetida especially when it is sophisticated.

Many therapeutic properties have been ascribed to asafoetida. Besides, Bose *et al*[9]. reported

that asafoetida oil exhibits germicidal effects. Bhat and associates[10] in an *in vitro* study on microbiological fermentation found that asafoetida had no bacteriostatic properties, but increased the H_2/CO_2 ratio which might explain the reputed carminative action of asafoetida.

Sreenivasamurthy and Sastry[11] studied the effect of oral feeding of asafoetida oil (0.02 ml. of 1 per cent oil in groundnut oil) on the intestinal microflora of the rat, as also its effect *in vitro* on some of the isolated intestinal organisms. They found that coliforms and anaerobes decreased, but acid formers increased in the ceca of the experimental animals as compared with control group. *In vitro* incubation of the cecal contents with asafoetida oil, however, increased the coliforms. With *Streptococcus faecalis*, similarly treated, there was pronounced inhibition in the rate of multiplication, a marked increase in cell size and a loss of viability after 24 hours incubation. Gardner[12] had earlier recorded 'swelling' in this organism after penicillin treatment. Using the intestinal loop, Sastry and Sreenivasamurthy[13] showed that asafoetida did not influence the absorption of glucose by the small intestine. Patwardhan and Sastry[14] found that an emulsion of asafoetida did not significantly alter the activity *in vitro* of the intestinal (Wall) enzymes of the rat. Although asafoetida oil is a disulphide in nature, Sastry[4] found no thiamine sparing effect with it, unlike allin, as determined in rat-growth studies. Satyanarayana and Kadkol[15] analysed a number of market samples of asafoetida for vitamins and found them to be present only in traces.

Garlic

Krishnamurthy and Sreenivasamurthy[16] have recently reviewed the physical-chemical and physiological aspects of garlic (*Allium sativum*), another well known spice. Raghunandana Rao *et al*[17]. have reported an improved method of isolation of allicin, of which the structure has been further studied by Rao and Varma[18]. Some minor constituents have been isolated by Datta *et al*[19]. Ananthakrishnan and Venkataraman[20] reported that 80 per cent of the total nitrogen in garlic was water-soluble and of this 67 per cent was non-protein nitrogen. The non-protein nitrogenous fraction was rich in lysine and histidine. They[21] also reported that 30.5 per cent of the total phosphorus was present in the phytin. The carbohydrates, according to them[22] consisted of starch, mannose and fructose. Their conclusion about starch runs contrary to their own evidence that the material gave no colour with iodine. The latter observation taken together with their finding that the polysaccharide isolated by them from garlic had a specific rotation of -41° and that it gave a strong Seliwanof's test was a clear indication that they were dealing with a fructosan type of polysaccharide. That it was really a glucofructosan was later shown by Srinivasan *et al*.,[23] using the paper chromatographic technique. Bhatia *et al*.[24] made a study of the carbohydrases in garlic.

A process[25] for the economic production of garlic powder of improved medicinal quality has been developed and factors governing dehydration[26], packaging[27] and storage[28,29] have been investigated at the Central Food Technological Research Institute, Mysore.

Ginger

India produces annually about 14,000 tons of dry ginger (*Zingiber officinale*)[30]. The essential oil of ginger has been studied[31,32]. Work done by Lal, Pruthi and associates includes improved methods of recovering ginger oil and the pungent principle which is an oleoresin[33], drying and dehydration of ginger and development of new products[34]. Of the latter, a soft drink developed by Johar[35] marketed under the trade name GINGERALLA is very popular. Four types of ginger powder *viz*., plain 'Gin-col'[35], vitaminised[34], effervescent[34] and vitaminised effervescent[34] have also been prepared. Ginger preserve and ginger candy are well known manufactured products in good demand. In sun-drying and curing of ginger, use of thin scrappings helped in quick and uniform drying, while through-draught dehydration reduced the time[34].

Pepper

Pepper (*Piper nigrum*) is one of the most highly priced among the indigenous crops of India. The total land under pepper is estimated at 2,00,000

acres spread over the States of Kerala, Mysore and parts of Madras. Out of an annual production of 24,000 tons, about 13,600 tons of pepper were exported in 1957-58 valued at Rs 2.8 crores in foreign exchange. About 20 varieties of pepper are cultivated, of which 'Balankotta' and 'Kallivally' varieties are high grade and heavy yielding.

Mitra and Roy[36] analysed different samples of genuine black pepper and some inferior adulterated products as well. Also a sample of papaya seed, a common adulterant of black pepper, was examined by them with a view to detecting it in pepper. Ramachandra Rao *et al.*[37,38] have briefly dealt with standards and grades of Indian pepper. Results of analysis of ten Indian varieties have been recorded by Dwarakanath *et al.*[39]

Till recently, piperine was being estimated as crude piperine based on the values for non-volatile ether extract or on alcoholic extract. The work of Fagen *et al.*[40] showed that pure piperine could be estimated by the spectrophotometric method both in the oleoresin and in the pure product. Ramachandra Rao *et al.*[41] have now isolated fairly large quantities of pure piperine from Malabar black pepper. The long, lemon-yellow crystals melted at 130°C and showed a maximum absorption at 345 mμ. An alcoholic solution of the crystalline material gave a characteristic pepper bite and flavour. Others[42] have attributed the 'bite' in pepper to chavicine, an isomer of piperine.

With a view to utilising trade waste of the pepper industry, analysis of the waste was carried out by Rao *et al.*[43] The results show that weight for weight pepper rejections gave a higher ether extract than even whole pepper. They have been able to extract the oleoresin from this extract which also carries the 'bite' and flavour fraction with it. By suitable treatment and processing, this can be combined with a salt base, and a single product for food flavouring obtained. They have thus prepared a product called 'Pepper-Sal', based on the above process, which has found acceptance as a flavouring agent for salads, drinks and meat dishes. Application for a patent for the process and the product 'Pepper-Sal', has been filed.

A study of the role of pepper in human physiology has just been started at this Institute.

According to Narasimhamurthy and Ranganathan[44], black pepper protein contains more cystine histidine and lysine than the proteins of the common cereals. By chemical method, Narasimhamurthy[45] found a riboflavin content of 152.0 γ per gram of pepper on fresh weight basis. Recently, Satyanarayana and Kadkol[15] have found an average value of 257 γ of riboflavin by microbiological method, 121 γ of thiamine by thiochrome method and 1800 I.U. of carotene by spectrophotometric method, per 100 gram of marketed pepper.

Saffron

Saffron, the dried stigma of the flowers of *Crocus sativus* (N.O. Iridaceae) is a native of South Europe, but is cultivated also in Kashmir. Once an important dye, it is now used chiefly as a flavouring and colouring agent for foods. Though somewhat bitter in taste, saffron has a delicate aroma which enriches the organoleptic quality, especially of sweet preparations.

Analysis of 25 genuine samples of saffron from Kashmir has been published[46]. Sastry *et al.*[47] have exhaustively reviewed the previous literature on saffron relating to its proximate chemical composition, the nature of carbohydrates and pigments, its medicinal and biological properties, standards as existing in different countries, as also the common adulterants and methods of detecting them, based on colour reactions. Sastry *et al.*[47] analysed a number of market samples and found, surprisingly enough, that the values conformed to those for genuine saffron. Their analysis also included values for gums and dextrins which had not been reported previously for saffron. They also showed chromatographically the presence of glucose, fructose, gentiobiose and traces of xylose and rhamnose. They commented that gentiobiose is present presumably as a product of hydrolysis of the pigment, crocin, to its aglycone, crocetin, which was also shown to be present in the samples.

The sample analysed by Sastry *et al.*[47] contained only 5 γ/g. of riboflavin and 0.4 γ/g. of thiamine in contrast to the high values reported by Bhatt and Broker[47a]. Bhatt, Broker and Iyer[47b] found that, in the concentrations normally used in indigenous milk preparations, saffron

inhibited the growth of spore-forming bacilli and stimulated the activity of digestive enzymes.

Turmeric

Turmeric (*Curcuma longa*) has been cultivated and used for centuries in India as a food adjunct in spicing and colouring and in medicine[48]. There is a large export trade for this product.

According to the current trade practice, the freshly harvested turmeric tuber or finger as it is called, is cooked in cow-dung water, dried and then gently polished to take subsequent colouring. At this stage, the tuber has an orange tint and a dull, undistinguished woody appearance. It is, therefore, artificially dyed yellow. The dye used so far consisted of a mixture of turmeric powder itself and chrome yellow (lead chromate) made into an emulsion with castor seed paste and alum as binders. Turmeric fingers so dyed are thus contaminated with lead and are not permissible for use in foods.

At the instance of the industry, the Central Food Technological Research Institute investigated the twin problems of replacing the cowdung used in the initial processing and of finding an alternative method of colouring the tuber without employing lead chromate. Desikachar *et al.*[49] found that addition of small quantities of a mild alkali like lime or sodium carbonate (or bicarbonate) to the cooking water imparted the same orange yellow tinge to the core of the tuber as cowdung water did. On the other hand, sodium bisulphite and hydrochloric acid (SO_2) bleached the orange colour preferentially, leaving a product with a bright yellow colour. For dyeing 150 lb. of the tuber, 20 g. sodium bisulphite and 20 ml. concentrated hydrochloric acid were required. The modified method has now been adopted by the turmeric manufacturers, thus eliminating the use of lead chromate.

Turmeric contains two pigments: one is orange and the other is yellow[50], the orange being more prominent. If the orange is suppressed, the yellow is shown up. This change from orange to yellow in turmeric powder to be used for dyeing the tubers, could be brought about by mixing the emulsion (slightly acidified) with small amounts of a permissible blue dye (Edicol Blue VRX or Indigo carmine) or by preferentially extracting the orange colour from the powder with alcohol or benzene, leaving a bright yellow residue.

Curry Powder

Spices are seldom used individually for flavouring foods. A blend of the spices herein described and others like coriander together with condiments like chillies is curry powder which holds sway as a rich delicacy in India and is greatly in use and demand. The particle size (sieve test) and sedimentation rates in petroleum ether and acetone of a number of curry powders of different blends were studied as a test of granularity with in conclusive results[51, 52].

Tamarind

A close associate of curry powder in Indian dishes as a condiment and important taste adjunct is tamarind pulp. About 2,30,000 tons[53] of it are produced annually in India, mostly in the South where it has a major use as an additive to give tartness to foods. Previous work relating to its chemical composition and utilisation has been recently reviewed by Lewis *et al.*[54] who have developed an integrated process for the isolation of solid pectin and tartaric acid from tamarind. There has been a large volume of work on a pectin-like constituent of tamarind pulp without an agreement on the question whether or not it is a true pectin[55, 56]. According to a more recent report by Lewis and Johar[57], this constituent is a true pectin, of which more is present in a red variety of tamarind fruit[58], the pigment here being an anthocyanin[59]. Chromatographic study by Lakshminarayan Rao *et al.*,[60] of the make-up of the free amino acids in tamarind pulp revealed a preponderance of proline, besides the presence of less common acids like pipecolinic acid and β-alanine.

The effect previously reported that on diets, which included tamarind, rats showed weight gains[61, 62], has now been traced to calcium[63] in the crude common salt of which extra quantities are necessarily ingested with tamarind-containing food preparations like *Rasam* and *Sambhar*.

Conclusions

A noteworthy finding on spices, among which is curry leaf (*Murraya koenigi*), is their anti-

oxygenic property and consequent capacity to preserve fatty foods from spoilage[64, 65, 66, 67, 68]. Many medicinal properties have also been attributed to spices, a well established one being the carminative action due to their essential oils. There is, however, paucity of scientific knowledge as regards their disposal and physiological role in the human system. There is need to acquire this knowledge, since foods in India, especially in certain regions, are highly seasoned and in this manner fair amounts of spices and condiments get ingested. Investigations described here, which to a large extent represent the work at the Central Food Technological Research Institute, Mysore, are a beginning in that direction.

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RECENT RESEARCHES ON COFFEE AND TEA IN INDIA

By C. P. NATARAJAN

(*Central Food Technological Research Institute, Mysore*)

India is one of the major producers of tea and coffee production is also on the increase. Research on cultural and technological aspects have been carried out till recently in the Research Stations established by the Planters Associations at Tocklai and Davershola in the case of tea and by the Coffee Research Station, Balehonnur of the Coffee Board. The need for more intensive technological work was felt by the Tea Board and Coffee Board and under their auspices a unit was started for Coffee Research in 1952 and for Tea Research in 1956 at the Central Food Technological Research Institute. For Tea, a unit is also working in Calcutta University and plans are being finalised by the Tea Board for a Central Fundamental Tea Research Institute and a Tea Research Station in Dooars. The main aspects of the progress in the field will be discussed in this article.

COFFEE

Cultural aspects

Considerable attention has been given at the Balehonnur Research Station to the breeding of strains of coffee resistant to diseases and which give consistent high yields of quality beans; the three Arabica selections S 288, S 333 and S 795 are already under large scale cultivation. Experiments on the manurial requirements of coffee, land management with special reference to soil and moisture conservation were in progress for a number of years. Consequent on treatment with nitrogen and phosphorus, the yield increase was steady and high. Experiments on the field control of stem borer in arabica coffee using various insecticides like BHC, DDT, Folidol E 605, Aldrin and Dieldrin, etc., have been in progress. Field trials on spraying of coffee with various fungicides for comparing their efficiency with Bordeaux mixture have been in progress. The experiments on different agronomical practices like digging, pruning, weeding and manuring have been carried out and indications are that complete fertilizer (N 40=P 30=K 40) application in September and October, slash weeding in July and deep digging in August gave higher yields than other treatments. Studies on shade requirements, observations on setting of berries and berry retention are also in progress[1].

Processing of Coffee

Treatment of coffee with caustic soda accelerates the process of removal of mucilage and a number of plantations are adopting this technique for

Robusta coffee[2]. Field trials using *Benefax* a proprietary pectic enzyme preparation for quick removal of the mucilage have been successful[3]. Preliminary trials on the effect of rapid removal of mucilages on the final weight of coffee indicated that less loss in weight occurs when mucilage is removed rapidly from raw parchment[4]. Use of cherry husk ash and banana stem ash for removal of mucilage has been suggested[5].

Work has been in progress on the removal of fruity smell in new cherry coffee. Washing of fruits before drying did not eliminate fruity flavour[6]. It was shown that washing of beans with 0.5 per cent solution of calcium chloride and sodium chloride eliminated constituents responsible for fruity flavour[7]. The fruity flavour decreases during storage of cherry coffee and is practically eliminated in coffee stored for 5-6 months. The fruity flavour disappears[8] quicker when coffee is stored as beans.

Monsooning of Coffee

Studies on the changes in coffee during monsoon have been followed by determining moisture, weight/volume ratio, microbial count and changes in colour and chemical constituents. Increase in moisture in bean from 9 per cent to 15 per cent, increase in weight/volume ratio and microbial counts were observed. The colour gets bleached and the total nitrogen seems to increase on storage[9]. Laboratory studies simulating the monsooned conditions of storage also confirmed the observations mentioned above[10]. The role of microbial activity in modifying the brewing characters of monsooned coffee and the nature of the organisms involved are subjects of further studies.

Storage of Coffee under Humid Conditions

In order to determine optimum conditions of storing coffee without absorption of moisture, laboratory and field trials have been undertaken. Preliminary trials have indicated that by adopting the 'Ballooning process' of storage of coffee under 300 gauge polythene cover, it is possible to keep coffee in good condition. Under air tight conditions coffee stored well in metal bins, the daily temperature variation being of the order of 11° C. Studies on bulk storage of coffee in cement bins are also in progress[11].

Chemical Composition and Standards for Coffee

With a view to fixing suitable standards for Indian coffee, coffee samples belonging to Arabica and Robusta varieties and types from various regions of growth have been analysed and suitable standards suggested[12].

Adulteration problems in Coffee

Considerable work has been carried out in developing simple tests for detecting the common adulterants like roasted date seed and tamarind seed in coffee. One simple method has been evolved[13] and a field test kit is in use by the Coffee Board. A quantitative method for estimation of adulterants is also being worked out.

Studies on Coffee Brewing

Scientific data on coffee brewing were collected and the influence of grind, roast, nature, time and temperature of contact with water, ratio of water to powder, influence of metals on aroma, efficiency of extraction with various brewing devices, use of diluted milk as an extractant for fixing aroma in coffee have been studied in detail[14]. A simple technique such as wetting the powder with water before passing hot water significantly increases the extraction[15]. A hydrometer device to assess the strength of brew and thereby the efficiency of extraction and quality of brew has been devised[16].

A filter device for brewing coffee quickly and efficiently has been evolved and such filters are on sale through the Coffee Board[17].

Studies on the stability of polyphenols and caffeine in coffee brew have been shown that the two constituents are stable[18]. The chemical composition of brew has been ascertained as follows: (on soluble solid basis) caffeine, 4.4 per cent; chlorogenic acid, 14 per cent; crude protein, 14 per cent; total sugars, 21.9 per cent; ash, 14.5 per cent and colouring matters 15.4 per cent[19].

Roasting of Coffee

Detailed studies on various changes, such as those in colour, swelling, density, breaking strength, temperature-time relationship, chemical

constituents have been made. A method of controlling roast by fixing the finishing temperature for each roast with reference to the roaster has been suggested. Colour development is proportional to finishing temperature of roast up to 240°C. For swelling, a finishing temperature not less than 225°C is necessary. The breaking strength and swelling ratio seem to define the roast better than temperature-time relation[20].

Soluble Coffee and Freeze-dried Coffee

Data on the methods of extraction and drying characteristics of coffee as such and in combination with additives have been collected[21].

Further work on improving the aromatic qualities of spray dried coffee is in progress.

Insect control in Coffee

Insect infestation is a problem in monsooned coffee and studies on fumigation with methyl bromide and ethylenedibromide at different doses from 1-4 lb. per 1,000 c. ft. were undertaken. It has been shown that at effective doses, the bromide residues were within limits and that the fumigation does not in any way impair the cup quality[22].

Miscellaneous work

The chlorogenic acid content of Indian Coffee has been estimated[23].

The antioxidant properties of coffee have been shown[24]. Coffee seems to inhibit the growth of bacteria[25]. Utilization of coffee husk as a substitute for chicory has been indicated[26a].

Coffee stimulates the gastric activity by increasing the free and total acidity as well as pepsin activity in stomach. Coffee does not affect the *in vitro* digestion by trypsin[26].

TEA

Tea Culture

Considerable work has been in progress on various aspects of tea culture and manufacture at Tocklai Experimental Station and Scientific Department of United Planters' Association of South India. Considerable attention has been paid to tea breeding, morphology, taxonomy of tea plant[27]. Long period manurial trials have been in progress at both the stations. In Devershola it was observed that continued omission of phosphoric acid in the manure over a period of 17 years did not affect the yield adversely[28]. Field control of blister blight, mites and tea mosquito bug, screening of fungicides and other insecticides continue to receive much attention[29].

Manufacture

The chemical changes that take place during withering have been under detailed study[30]. An increase in extractable caffeine during withering has been observed. Caffeine stimulates also oxidation of catechin. Tunnel withering has been tried and no adverse effect on plain tea is noticed. Development work on design of continuous rolling machines was pursued[31] and teas made in continuous rollers have been preferred by tea tasters[32]. Field trials were conducted on the performance of mechanical harvesting machine and suitable modification for improving its efficiency was suggested[33]. A full scale commercial leaf trolley, a prototype of continuous withering machine and modifications for improvement of the performance of continuous rollers and development of mechanical pruning machines are other important advances in tea technology[34].

Biochemical Studies

Appreciable enzyme activity and consequent slow fermentation in teas stored after firing was noticed[35]. Studies on the isolation and identification of compounds responsible for tea aroma were in progress. A method based on oxidation of volatiles on steam distillation by permanganate has been suggested for evaluation of aroma[36]. Work on chemical basis of quality has been started[37] by following the changes in soluble solids, total polyphenol caffeine, rate of consumption of oxygen during fermentation, ethyl acetate extractable and non-extractable portions in made tea. Samples showing more total polyphenols, caffeine and Qo_2 in fresh leaf ranked higher in taster's assessment. Caffeine and water soluble solids in fresh leaf were correlated with strength, quality and briskness[37].

Biochemical work specially on the polyphenolic constituents[38], amino acids[39] and carbohydrates[40] was carried out in U.K. at the Indian Tea Association Laboratory.

Area in acres	Production	Main regions of cultivation	Research Institutions and their main activities
TEA		**North India**	
7,91,872	664 million lb.	Assam Dooars Terai Darjeeling Cachar	(1) Tocklai Experimental Station, Cinnamara, Assam: Tea breeding, pest infestation control, agronomy, biochemistry, engineering and quality aspects. (2) Tea Scientific Department, United Planters' Association of South India: Botanical, pest infestation control and manurial trials.
		South India Nilgiris Wynad-Mysore Annamalais High Range Travancore	(3) Central Food Technological Research Institute, Mysore: Chemical composition and technological aspects, soluble tea and quality aspects and packaging. (4) Calcutta University: Nutritional aspects and biochemical aspects.
COFFEE (for the year	1957)		
2,60,400 (1,60,686 under Arabica) (99,715 under Robusta)	44,149 metric tons	Bababudans Mysore Coorg Wynad Naduvattam Nilgiris Nelliampatti Shevaroys Annamalais Palani Kannan-devans	(1) Coffee Research Station, Balehonnur: Breeding, pest controls, manurial trials and processing. (2) Central Food Technological Research Institute, Mysore: Chemical and technological aspects, brewing, soluble coffee, storage problem, insect control and packaging.

Chemical Composition of Tea

In view of the fact that tea is grown in a wide range of climate, altitude and soil conditions, it was considered desirable to collect information on the chemical composition of tea collected from various estates in South and North India, selected so as to represent a range of climatic and topographical conditions and management factors. Data on over 1,000 samples have been collected and observations on seasonal and grade variations have been made. Suitable chemical standards for tea have been suggested[41]. Similar data have been collected by Sengupta *et al.*[42] Mitra and Roy[43] reported figures for caffeine, tannins and fibre. Other reports on some chemical constituents of the market samples[44] are also available.

Adulteration of Tea

Studies on methods of detection of adulteration in tea with materials like spent tea, saw dust, blackgram husk, etc., are in progress[45].

Nutritive Value of Tea

Guha and collaborators have reported on the vitamin content of Indian tea[46]. The average values for the vitamin (μg/100 g.) on dry basis are: thiamine, 135; riboflavin, 1266; folic acid, 76; pantothenic acid, 1260 and nicotinic acid, 7500. It has been observed from experiments on guinea pigs fed with green tea infusions that it helps in the retention of vitamin C in the body. This effect is not observed with black tea.

Tea Concentrates and Soluble Tea

Work is also in progress in the Central Food Technological Research Institute, Mysore for evolving suitable methods for making tea concentrates and soluble tea in which the tea flavour is fully conserved. A liquid concentrate for ready-to-serve lemon tea has also been evolved.

Quality versus Cup Tasting

It has been a problem to correlate the cup tasters' report with chemical composition of tea so that an objective method of assessing quality in tea can be evolved. Work in this direction is being carried out both at Tocklai and the Central Food Technological Research Institute, Mysore.

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ADDITIONAL FOOD RESOURCES IN INDIA—RICE BRAN, COTTONSEED AND GROUNDNUT

By Y. K. Raghunatha Rao

(*Central Food Technological Research Institute, Mysore*)

India is a large producer of rice and oilseeds, like groundnut and cottonseed. In spite of such production, India is deficit in food and vegetable oils. It is planned to increase the agricultural outputs of these food materials. But it is also advisable and necessary to make the best and complete use of these raw materials which are already being produced and are partly wasted for lack of a thoughtful procedure. The present industrial practices in the country do not utilize completely such existing food resources by recovering all the possible food materials.

Rice Bran

Adequate attention has not been drawn to the wastage of the by-products of the rice milling industry, mainly the rice bran and polish. In some parts of the country, rice hullers are employed to separate the brown rice from the husk or paddy hulls with the result that the bran gets mixed up with the powdered hulls and is lost for edible purposes[1]. In several rice mills, however, rice polishers are employed. After the milling of brown rice, it is sent to the cone mill, where the bran or polish is obtained as a separate product. Bran is popularly used as animal feed for which there is a large demand. *But the bran contains* 15 *to* 25 *per cent of recoverable oil* (Table I) *which could supplement our existing oil resources* This oil is being extracted and recovered in Japan, U.S.A.[2] and very recently in Burma. The same thing can be done profitably in India to an increasing extent, with larger recoveries of the edible and industrial grade oils. In the above countries, a hydrocarbon like normal hexane is being used as a solvent for the extraction of the oil. It is necessary to employ the solvent extraction method in India and recover this highly valuable oil.

Table I. *Composition of rice bran*

Moisture %	8.9–12.5
Oil %	15-25
Protein %	10.6–13.4
Fibre %	9.6–14.1
Ash %	9.3–14.3
Pentosans %	8.7–11.4
Tocopherols %	0.025
B-vitamins %	0.67

Cottonseed

Cottonseed is being processed on a scientific basis in U.S.A. and other advanced countries, for recovering the four products—lint, hulls, oil and meal—which have several uses in industrial production of textiles, in animal feeding and also as human food. It contains 15-18 per cent recoverable oil. In India, the production of cottonseed is 1.5 million tons a year[3]. A major part of the seed is used directly as animal feed. This is an uneconomic procedure. Factories have recently been set up to crush the whole seed and obtain a low yield of a low grade oil. A few factories follow a more efficient process of delinting and dehulling the seed and then pressing the kernel to obtain the oil.

An improvement over this crude method is to extract the kernel by a solvent to obtain larger yield of the oil and a better grade of extracted meal. The existing factories in India employ normal hexane as the solvent for this extraction.

The present annual output of cottonseed oil is only 10,000 tons[4], whereas the possible recovery could be over 2,00,000 tons.

Groundnuts

The large annual production, 2.89 million tons (1955), of groundnut (kernels) in India[5] is being utilized in two ways. The groundnuts are eaten as such, raw or roasted. The major quantity of groundnuts is pressed in expellers and ghannies to produce edible oil and oil cakes. The modern and economic procedure is to prepress the groundnuts to obtain a high quality edible oil, and then to solvent-extract the pressed cake to obtain the maximum amount of recoverable oil and a good quality extracted meal. But very few factories are following this procedure in India. The common solvents employed are

normal hexane and other petrol fractions in the extraction of oil-cakes, for which there are many factories operating in India. But, a drawback in this procedure is that the commercial oil-cakes at present produced are of such inferior grade to be of little use from the edible point of view. The extracted oil-cakes are now being utilized only as manure and partly as animal feed.

There have been many attempts for the better utilization of groundnuts in the production of vegetable milk and curds[6], proteins from the groundnut cake and production of groundnut flour from selected groundnut cakes[7]. There has been no attempt to produce synthetic fibre from groundnut protein in India.

But in spite of the known processes of solvent extraction of oil seeds and cakes in the other parts of the world, India has not yet advanced in the *complete utilization of its existing oil resources.*

Rice Bran Oil and Meal

The production of rice in India is 28,000,000 tons annually. During milling, 8-9 per cent of rice is obtainable as rice bran[8]. It is also called rice polish. It is estimated that over 20,00,000 tons of bran is annually produced. By the hand pounding of rice, less than 6 per cent of the rice is obtained as bran. Samples of bran from rice mills in the different regions of the country have been analysed and they contain 15-25 per cent oil[9]. If all the bran were utilised for the extraction of oil, the quantity of rice bran oil produced (calculated at 15 per cent) will be 3,00,000 tons annually, valued at over 40 crores of rupees per year. The collection of bran from all over the country and its utilization require organisation and time. But, immediately a considerable amount of bran can be collected easily from the modern rice mills concentrated in the rice growing regions of India. By processing fresh bran from the rice mills in suitably located extraction factories, a high grade edible oil can be obtained. The production of this edible oil will be a very valuable addition to our food supplies.

When bran is stored for several days and weeks, acidity develops in the oil and on extraction, a high acid oil suitable for making soaps is obtained. This oil will naturally release the edible oil now being utilized for soap making. To facilitate the preservation of bran, fresh bran should be heated and dried and stored in a dry condition[10].

The bran from parboiled rice is also rich in oil, yielding 20-25 per cent of oil. After extraction, the bran from parboiled rice is free from the odour and is quite acceptable to cattle as a feed. Unlike bran from raw rice, the bran from parboiled rice has an objectionable odour before extraction. On account of the removal of the oil extracted bran has a higher protein content and therefore a better nutritive value. Unlike the original bran, which on account of its oil and moisture contents, turns rancid and causes loose motion of the bowels in animals fed with old bran, the extracted bran keeps very well in storage. Since the extracted bran is richer in protein and is more stable, it is sold at a premium.

Rice bran oil is similar in composition (Table II) to groundnut oil. It is more nutritious, being richer in some vitamins. It has also some medicinal properties. Experiments are being carried out both in India and in U.S.A. for studing its medicinal properties. Rice bran oil is popular as a domestic cooking oil in U.S.A. and Japan. It is winterised to make a salad oil. It may be hydrogenated to produce a solid hydrogenated product. Rice bran oil and the hydrogenated rice bran oil have greater stability than groundnut and cottonseed oils and their hydrogenated products[11]. There is no doubt that rice bran oil will be quite popular in India too, as a cooking oil.

Extracted Bran as Food: Rice bran as such is being already used in small quantities in making

TABLE II. *Composition of rice bran, groundnut and cottonseed oils*

	Rice Bran oil	Groundnut oil	Cottonseed oil
Iodine value	98–104	95.0	109.2
Unsaponifiables %	3.0–5.7	0.5	0.5
Smoke point °F	415	445	425
Flash point °F	615	625	613
Fire point °F	665	680	683
Cloud point °F	34	40	38
Solid point °F	18	34	28
Fatty acid composition:			
Saturated %	17.6	20.0	24.0
Oleic %	47.6	50.0	24.6
Linoleic %	34.0	30.0	51.0
Linolenic %	0.8	0.0	0.0

biscuits. After extraction of the oil, the fine grade of extracted rice bran is edible and can be used extensively in the country, mixing it with wheat or ragi, in making biscuits, chapaties, puries, puddings and sweets. The bran can enter into several food compositions, enriching these with minerals, vitamins and proteins (14-16 per cent), which are present in rice bran. Thus rice bran will be an additional food resource.

Cottonseed Meal and Flour

The extraction of cottonseed kernel by a high grade solvent, like ethyl alcohol, extracts the oil in a semi-refined state. The edible oil can be obtained by refining this raw oil. The extracted cottonseed meal is free from toxic gossypol[12, 13], which is removed by the alcohol solvent. The cottonseed meal is rich in proteins (35-42 per cent) and therefore could be utilized not only as animal food but also as human food, entering into several common foods in suitable mixtures with other food materials like wheat. Cottonseed flour is agreeable in flavour, colour and nutritive properties, to be deemed as an *additional food resource* of the country. Cottonseed meal has been found to be nutritious in several animal experiments[14].

Groundnut Flour

The extraction of prepressed groundnuts yields the edible oil and also the extracted edible grade groundnut meal. This is free from toxicity from residual solvent, when a solvent such as *ethyl alcohol* is employed for oil extraction[15]. Groundnut flour is rich in proteins (49-57 per cent), and low in fibre (4-5.7 per cent), and can be used in mixture with other ingredients of food. A considerable quantity of the protein-rich groundnut flour would therefore become available as an additional food for the country.

Extracted groundnut meal can also serve as raw material for recovery of proteins and for other industrial uses e.g., in making textile fibres.

Researches have been carried out at the Central Food Technological Research Institute with a view to processing these raw materials by an improved extraction method and with the object of utilizing all the by-products. The drawbacks in the imported solvents, in regard to their cost, the necessity of foreign exchange and the possible toxicity of solvent residues in the extracted food products, made us look for an indigenous solvent, free from these defects. We have found that an indigenous solvent which is produced abundantly by the Indian sugar industry satisfies the demands for an additional and alternative solvent for the production of edible extracted food products as well as for the efficient extraction of vegetable oils from various oil-bearing materials such as those mentioned above.

It is well known that industrial or absolute ethyl alcohol is a poor solvent for oils at the ordinary temperatures but it is not equally well known that it is a very efficient solvent at temperatures near and above its boiling point. A method (Indian patent No. 46793, 1952) was developed by which ethyl alcohol could be employed as a solvent for extracting almost all oil-bearing substances. A series of pilot plant experiments have been conducted during the last five years to determine the technical and economic feasibility of the extraction process. For these experiments, the pilot plants were

TABLE III. *Vitamins and other constituents in rice bran*

Particulars	Rice Bran and Polish per cent	Rice Germ per cent
Moisture ...	9.8	10.9
Fat (oil) ...	13.6–16.4	11.5
Protein ...	9.1–10.48	14.9
Ash ...	12.0–13.2	6.2
Nitrogen ...	1.5– 1.76	2.5
Phosphorus ...	1.4– 2.4	2.1
Calcium ...	0.13	0.27
Iron ...	0.02	0.01
Vitamins	Micrograms per gram of dry material	
Thiamine	24–22	65
Riboflavin	2.2	5
Pyridoxine acid	25–28	16
Pantothenic acid	11.6–9.9	30
p-Aminobenzoic acid	0.75	1.0
Nicotinic acid	336–330	33
Inositol	4627–5536	3725
Folic acid	1.4–1.9	4.3
Choline	1700–1020	3000
Biotin	0.6	0.6

* M. C. Kik, *The Nutritive value of Rice and its by-products*, Agr. Expt., Station Univ., Arkansas—Bull. 589, 1957.

designed and constructed in the workshop of this Institute and these pilot plant tests have been carried out for several years with several batches, each of 2-3 cwts, of the raw materials. These pilot plant experiments have amply confirmed the soundness of the processes and the economics of commercial extraction. It is proposed to set up shortly commercial regional units, which will lead the way to the gradual setting up of many more factories by the private sector.

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EQUIPMENT FOR FOOD INDUSTRIES, THEIR DESIGN AND MANUFACTURE IN INDIA

By S. K. Lakshminarayana and P. K. Ramanathan

(*Central Food Technological Research Institute, Mysore*)

PART I

The establishment and development of food industries need a variety of equipment and machinery most of which are at present being imported from other countries. Only limited amount of effort has been made to develop the indigenous manufacture of food machinery in India.

The Indian equipment manufacturers have been making quite a number of standard equipment widely used in the manufacture of oils, *vanaspati*, sugar, cereals, dairy products, etc. But, in the case of specialised equipment, the industrialist has necessarily to rely on design equipment because few manufacturers can afford to undertake research for new designs. In such cases, the National Laboratories have an important role to play. They have to convince the industry that it is possible to manufacture the specialised items of equipment in India and show them that the equipment made here is not in any way inferior in performance or elegance to the imported one and that it is not necessary to import such items as could be fabricated here. There is, therefore, a paramount need to develop this basic engineering industry to feed a number of fine chemical, food and allied industries. No systematic record of the import of food machinery and their value is available from any source, as this figure has been merged with imports of all chemical and allied equipment. It is, however, estimated that this runs into a few crores of rupees every year. It is, therefore, considered worthwhile not only to save this drain on foreign exchange but also to develop the industry so as to be self reliant.

The Central Food Technological Research Institute, Mysore has been trying to do its share of work in this direction and has designed and fabricated a number of specialised items of useful equipment for food processing. Some of these can also be used for chemical processing.

An idea of the work done can be gauged by a reference to the following:

(1) Falling film evaporator. (2) Forced circulation evaporator. (3) Rotary drier. (4) Thin layer evaporator. (5) Vacuum shelf drier.

Such work not only saves a lot of foreign exchange but also gives us valuable experience and confidence so essential for the design and manufacture of such equipment in India. The Government of India, it is learnt, permits its various Departments and factories, to pay even

higher price for Indian made equipment in preference to imported items. This is a step in the right direction and will help to encourage Indian machinery manufacturers considerably.

A survey of the types of units required for various operations indicates that the following six categories could be fabricated without much difficulty.

1. Heat exchangers, Evaporators and Condensers, etc. 2. Dehydration units. 3. Distillation and allied equipment. 4. Crushing, grinding, pulverising and size separation units. 5. Mixing and blending units. 6. Filtration and allied equipment.

With the existing workshop facilities and skill available in India, it is difficult to make equipment like Super Centrifuge, certain types of filters, and some other highly specialised units. But as we progress, it might be possible to take up the manufacture of these also.

It was opined recently that there are good workshop facilities in India, but what we lack is 'design'. To some extent this is true. Many interpretations are given by different people for this important term 'design'.

'Design' generally means a pattern or sketch with dimensions delineating the sizes required, so as to guide the plant manufacturer in fabrication. Generally, a designer applies well known physico-chemical principles to the operations involved and arrives at the sizes of the component parts and makes a sketch accordingly. Theoretically, this is the correct procedure to be followed. It often happens, however, that this may be totally unrelated to the actual practice. In such a case, if such a 'Design' is taken up for execution by any General Mechanical Engineering Workshop, many difficulties may be experienced in the execution and finally the equipment may not give the desired performance. A person who has actually handled a variety of similar equipment will be able to prepare a better design and if this is correlated with the theoretical as well as the practical difficulties which are likely to be encountered during fabrication, generally a good design results. One can normally expect an equipment thus designed to give the desired performance. Here again some people stress only the utility aspect and do not attach much importance to elegance. This is not a desirable feature from the point of view of industrial equipment which have got to be marketed. For persons who buy such equipment and who are not well versed in the details of the design, ease of operation and elegance are important, and actually add to the utilitarian aspect.

There are several factors which have to be considered in the designing of chemical plants in general and food processing equipment in particular. They are:

1. The function of the plant desired, including such process variables as capacity, pressure or vacuum, temperature, etc.
2. Sizes of the individual units for the desired functions.
3. General arrangement of the units considering (*a*) ease of setting up and dismantling, (*b*) ease of operation, (*c*) most economical way of giving service lines, such as water, steam, etc., and providing minimum number of bends, in the pipe lines for the services and the product, (*d*) ease of opening and cleaning, thus enabling the units to be shut-down for the minimum periods for cleanings, (*e*) position of observation windows or sight and light glasses, (*f*) ease of charging and discharging of materials, (*g*) steamline and elegant layout occupying the minimum floor space, (*h*) instrumentation, and (*i*) materials of construction of individual units.

In many cases the design will have to be limited by: (*a*) Plant fabrication facilities available in the Workshop. (*b*) Materials of construction available in the country or procurable from outside within a reasonable period.

With the initial experience gained in the matter of design and fabrication of certain equipment, better plant fabrication facilities have to be built up from time to time and thus the scope of work increased. As far as possible the design has to be adjusted to the indigenous raw materials, but where such raw materials like stainless steel, tin, etc., are not available, recourse should be had to imported materials.

Taking as an example one of the items of equipment designed and fabricated by us at the Central Food Technological Research Institute, Mysore, we give below how we have reconciled the above mentioned factors in the design.

Our idea was to design and fabricate a single pass thin layer evaporator for low temperature concentration of viscous liquids.

The evaporator has been designed for a capacity of 100 lb. of water per hour. One square foot of heating surface is provided. As this is an experimental unit, a large number of factors have been assumed and provision has been made for the variation of a few factors over a wide range, to determine the best operating condition.

The film of viscous liquid passing down the heating surface is mechanically sheared by means of rotating vanes to form a thin layer on the heating surface. As the rate of evaporation is dependent upon the speed of rotation of the vanes and the clearance between the vane and heating surface, the values of the clearance and the R.P.M. of the rotor have been arbitrarily fixed. Based on the best operating results of these factors, a bigger model will be designed. The vanes can be rotated at different speeds. As the evaporation takes place under vacuum all the joints are made leak-tight and at the same time is provided with quick opening devices. The vapour separator forms an integral part of the heat exchanger. The rotating vanes which run through the separator give a centrifugal force to the vapour thus serving as an entrainment separator and all the liquid particles are deposited on the walls of the separator. The unit is provided with a 10 sq. ft. condenser through which water at room temperature or chilled water can be circulated. The rate of evaporation can be watched through the all-glass receivers fixed to collect the concentrated product and the condensed vapours. There are no pockets anywhere in the product line where the material can accumulate. The rotor, baffles, receivers, etc., can be dismantled for cleaning in a matter of minutes. The whole unit occupies a floor space of 2′×2′ only with easily accessible valves making the unit compact. As far as possible the equipment has been streamlined to give it an elegant get up.

The material of construction of parts of evaporator, which come into contact with material handled is austinitic stainless steel of F.D.P. quality containing 18 per cent chromiu 8 per cent nickel, and 1.2 per cent titanium. the seams are welded by the Arc and Argon welding processes to prevent weld decay. Gr care and precautions are taken during welding minimise distortion and buckling. The units highly polished without any dents or pits. sharp corners are rounded to avoid accumulat of food materials which may start fermenti To minimise the use of stainless steel whicl not available and which costs nearly 12-15 tin the cost of mild steel, parts of the units which not come into contact with the materials hanc in the evaporator are made of mild steel copper. In some cases stainless steel and n steel reinforcement is used.

It incorporates all the facilities mentio earlier for setting up, dismantling, operat cleaning, charging, discharging, provision variation of the capacity of the forcing pu etc. The fabrication of the unit is now comp and the same is now under test.

As we have no facilities to make use of accessories in India, these have to be impor These accessories could also be manufacture India provided there is sufficient demand. only limitation which we had to keep in n throughout was that no individual part shculd l a diameter of more than 24″ to correspond tc machining facilities we have at the moment. however, hope to improve this facility sho and we may then hope to have parts even u 36″ diameter.

Some of the other items of equipment desig by us and which are in the process of fabrica at present are:

Rotary Vacuum drier, Forced circula evaporator, Equipment for solvent extractio rice bran, cottonseed and other oils un pressure, Powder mixers, Vacuum contact p dehydration equipment, Inclined impact te for packages, Vacuum pan, Equipment parboiling paddy, and Driers for parbo paddy.

PART II

FABRICATION WITH STAINLESS STEEL

Materials of Construction

The materials of construction one comes across in the field of Food Processing equipment cover a very wide field and include many ferrous and non-ferrous metals and non-metallic materials. Before the advent of stainless steel and some of the plastics, copper and its alloys, aluminium and other non-ferrous metals were used. The parts made of copper were either heavily tinned or nickel or chrome plated to avoid copper contamination. While corrosion was not a very serious problem, contamination of the food materials with the metal had to be avoided. This resulted in the high recurring expenditure on periodical tinning or electroplating, in addition to the difficulties involved in the process. With the advent of stainless steel, it became increasingly popular both in the matter of domestic utensils and in Food Processing equipment. The chief reasons for this popularity, though stainless steel was twice or thrice as costly as copper, brass, aluminium, etc., were: (*a*) There would be no disagreeable metallic contamination. (*b*) Stainless steel would be more resistant to corrosion. (*c*) Stainless steel would be cleaner and brighter and would retain its polish for a long time, making it easy to clean, thus help in maintaining good sanitary conditions, which is a very important and desirable feature in Food Processing equipment. (*d*) Stainless steel was stronger and tougher and there would be less wear and tear in use. (*e*) Recurring expenditure in the matter of tinning and electroplating would be avoided.

Stainless steel is not manufactured in India at present. But with the increasing popularity of stainless steel, it is necessary to undertake its manufacture in India to avoid the drain on foreign exchange. This has been contemplated and before long we may hope to see and use Indian made stainless steel.

Stainless steel presents a number of fabrication problems, apart from the usual ones that we may come across in the case of any other metal. Special precautions are necessary in the matter of forming, welding, machining, grinding, polishing and other fabrication techniques.

Welding of Stainless Steel

A wide variety of stainless steels have been developed with varying percentages of either chromium or admixture of chromium and nickel as the chief alloying elements. They can be broadly classified into the following categories:

1. Straight chromium steels containing up to 14-18 per cent of chromium with carbon content up to 1.2 per cent. These behave like plain carbon steel and can be subjected to heat treatment and harden appreciably on quenching. These types are unsuited for deep drawing and forming and cannot be welded satisfactorily. As such they are unsuitable for fabrication. They can be used where corrosive conditions are not severe. This type of steel is generally used for ball bearings, needle valves, springs, cutlery, etc.

2. Increase in the percentage of chromium up to 28 per cent with addition of traces of certain other alloying elements like sulphur, aluminium, manganese renders the steel non-hardenable by heat treatment. These types when welded loose their ductility and get brittle. Consequently, they cannot be used where strength against bending and shock loads are required. These types of steel are used in high temperature service which require resistance to sealing. They are used for gas and electric cooker parts, oil burners, all metal radio tubes, furnace parts, aeroplane jets, etc.

3. The third variety consists of steel containing 16-20 per cent chromium and 6-12 per cent nickel. These are the types of steel we commonly come across in the fabrication of food processing equipment. They are commonly referred to as Chrome-Nickel Austenitic stainless steels. The term itself indicates that the high temperature austenitic condi-

tion is retained at ordinary temperature by addition of chromium and nickel in requisite amounts. These contain a maximum of 0.15 per cent carbon. These are non-hardenable by heat treatment and can be used under severe corrosive conditions and high temperature service. Best results are obtained by addition of 2-4 per cent molybdenum, which increases the resistance to corrosion.

The 18/8 chrome nickel steel generally used in food machinery comes under this category. This contains up to 0.08 per cent of carbon and 2.5 to 4 per cent molybdenum. These steels can easily be formed, deep drawn, rolled and most important of all, welded. Some types of this steel, which do not contain stabilisers and contain 0.12 per cent carbon must be heat-treated after welding. The 18/8 steels containing less than 0.08 per cent carbon and with stabilisers do not need heat treatment after welding.

Stainless steels are fundamentally different from normal structural steel and have the following mechanical properties: Thermal conductivity 112 BTU/sq. ft./hr./°F/inch *i.e.*, about 1/3 of mild steel; co-efficient of expansion 16×10^{6}/°F *i.e.*, 1.45 times that of mild steel and Max. Tensile strength 35-45 tons *i.e.*, 20-50 per cent more than mild steel.

The austenitic structure has some degree of instability and could be broken down by cold working.

The 18/8 stainless steel was being used freely in the construction of a wide variety of industrial plants and equipments. Very soon a serious defect was encountered in places where the material was welded resulting in the failure of welded joints, commonly known as weld-decay. The welded portion was found to lose its corrosion-resistance. The cause of this trouble was soon discovered and attributed to the precipitation of carbides of chromium. Before welding the carbides would be held in solution. During welding a narrow zone would be subjected to a high temperature above its transformation temperature. On cooling the carbon which existed as iron carbide and held in solution would combine with chromium forming chromium carbi which being insoluble would be thrown out of th solid solution. This carbide contains about 9 per cent chromium. Since the steel contain only about 18 per cent of chromium it was obviou that the extra amount of chromium needed t form the carbide was absorbed from the neigh bouring region. As such, the immediate vicinit of the weld would contain less than the requisit amount of chromium. As chromium is largel responsible for corrosion-resistance, the zone where the chromium was depleted would not b corrosion-proof.

This condition is prevented by two method The first consists in heating the welded area to high temperature above 1000°C when all th carbides go into solution and rapid cooling. Thi rapid cooling arrests the precipitation of carbid and holds them in solid solution. The limitatio to this method is the size of the equipment an can therefore be used only for small component These types of steel which require post-weldin treatment are known as unstabilised steel.

The second method consists in addition of sma quantities of other elements, which have stronger affinity to carbon than chromiur These elements combine with carbon in prefer ence to chromium and are precipitated on coolin and the chromium is unaffected. These element are known as stabilisers and the amount of th stabilisers required will be proportional to th carbon content of the steel. These types of steel do not require any post-weld heat-treatment, an are known as stabilised steels. The commonly use stabilisers are titanium and columbium and th steels are referred to as 18/8Ti or 18/8 Cb. steels

As regards the actual welding technique, a chrome nickel steels—both stabilised and un stabilised, could be welded by all the conventiona methods except forge-welding.

Oxy-acetylene welding can be easily adopte for welding thin sheets of the metal. Car should be taken to see that the flame is neutra The flame is first adjusted until it is definitel reducing. The acetylene is slowly cut down unt the last traces of feathering of acetylene are jus disappearing. As the welding proceeds the blo pipes get hot and tend to make the flame oxidisin This will require constant adjustment of the flam

Arc-welding by means of coated electrodes can so be adopted for joining these steels. The ated electrodes in addition to having the same mposition as the parent metal, also contain the abilisers like titanium or columbium. Alough titanium was found to be effective in abilising the steel, which was subsequently hot lled, it was found that it was not as effective for abilising arc-weld deposits. This was due to rious loss of titanium in electric arc by oxidation. crease in titanium content did not prove fective as the weld was observed to be porous. or this columbium provided the remedy. olumbium is not oxidised to such an extent as anium and as such is more commonly used in the ated electrodes even for titanium-stabilised steel.

Both A.C. and D.C. current can be used for elding stainless steel, although D.C. current is eferable, as it gives a steady arc and deep enetration. While welding with D.C. current, ie electrode is connected to the negative terminal. his type of welding is known as reversed polarity elding. This type which though has a lesser enetration than straight polarity welding is referred as it prevents contamination of welds.

The inert gas welding is an answer to the xidation problem encountered in the ordinary elding. The welding is done in an inert mosphere like argon or helium using either .C. or A.C. The arc is struck between a tungsen electrode and the parent material. The ream of argon forms a shroud and envelopes ie arc preventing oxidation or contamination of itrogen. Welding is done just like oxyacetylene elding using filler rods. Another advantage of is type is that the filler rods could be cut out om the same parent materials so that the weld eposit will have the same composition as the arent material, which on grinding and polishing ill not be in contrast with the adjacent parent ietal.

Stainless steel can also be welded to mild steel uch as mild steel reinforcements to thin plates. or this type of welding, electrodes with a higher ercentage of chromium and nickel to compensate or the dilution of the alloying elements, are sed.

Another defect encountered in stainless steel velding is the distortion of the welded joint. This is much more serious than in mild steel. The higher co-efficient of expansion and lower thermal conductivity produces permanent deformation at the welded area. This is an undesirable effect as even slight distortion will be magnified and detracts from the otherwise good appearance of the highly polished surface. Furthermore, this distortion will interfere with proper drainage which is of prime importance in chemical and food processing equipment of sanitary construction.

The distortion could be minimised by several ways. The first consists of a suitably designed joint, where the welds are positioned on a radius or curved surface. It is always desirable to have the welds away from corners. This will also facilitate grinding of the weld. It is cheaper in the long run to carry out extra-forming operations prior to welding, as for example, when a pipe is to be welded to a flat surface the pipe should be flared out to meet the contours of the surface.

The second method consists in the use of suitable jigs and fixtures. The jigs with chilling bar holds the sheet firmly in position during welding and prevents buckling. They also extract the extra amount of heat from the weld region. Use of jigs ensures higher welding speeds. The chilling bars or back plates are usually made of copper and will have a groove to coincide with the weld line. The use of chilling bars is limited to arc welding of long seams and are unsuited for gas welding since the rate of heat extraction would interfere with the welding operation. In places where it is not possible to use jigs it is a common practice to tack-weld the sheets at close intervals. After tack-welding, the two sheets are hammered into alignment and the weld run.

Since the major cause of distortion is contraction along the length of the weld, the sheet to be welded is first stretched to an extent which on contraction will be of the same length as the adjacent portion of the sheet. This requires considerable skill and experience.

Another practice is to remove the distortion in various stages of sub-assembly before they are finally welded together.

In thick plates, it is usual to employ the back stepping process, in which adjoining beads in a continuous seam are deposited in a direction opposite to the general advance of welding.

Cold working and Forming

All stainless steel alloys have greater resistance to cold deformation than low carbon steel, copper, brass, etc. It is for this reason that machines of larger capacity than would normally be used for the low carbon steel are used. One of the limitations of cold working of stainless steel is its work-hardening and as such, it has to be annealed before further deformation. The formed part is heated to 1700-1800°F and cooled rapidly. Greater allowance for the 'spring back' has to be made. The forming tools must have larger clearance to accommodate the springing. Dies used for drawing stainless steel have much shorter life and as such adds to the cost of fabrication.

Any damage to the surface during rolling and cold working will involve extra labour during the polishing stages. As a precaution use of a protective paper over the surface being rolled is advised.

Machining

Machining of stainless steel depends to a large extent on the type of cutting tool used. The mechanical properties which make these alloys so useful makes it so difficult for easy machining.

In single point turning, carbide-tipped tools are more usefully employed and have a much longer life than the other cutting tools. The top rake of the cutting tool will be from 5°-8°. Sometimes it is advisable to use a negative rake where intermittant cutting is encountered. The cutting tool should never be allowed to idle on the work or else work-hardening will set in. The motto would be 'KEEP CUTTING'.

Another limiting factor in machining is the slow cutting speeds necessary. The tool life is considerably lengthened and better surface finish is obtained by keeping the cutting speed below 100 ft. per min.

Grinding, Polishing and Buffing

Many formed, machined and welded parts require additional operations to improve the surface finish. The method employed will depend upon the nature of the job and the finish expected. A dull finish or what is generally known as dairy finish is given to equipment used in foo industries, where it is not desirable to give mirror finish.

During grinding the size of the abrasive w depend on the surface defects that are to b removed. Coarse grits from 60-80 are satisfacto during the first operation. Care should b exercised in grinding local defects to avoid dee cutting. Several grinding operations may b necessary depending upon the final finis required. The grit size is successively reduce from 80, 100, 120 and 150 and sometimes 20 to 300 if a mirror finish is required. Grindin scratches must be completely removed by fin grits before polishing. The finer grits of eme are coated on soft fabric and felt, for polishin High speeds of the order 3000 to 12000 r.p.r (i.e. a surface speed of 4000 to 8000 ft./min.) a usually employed during fine grinding. Ca should be taken during fine grinding to avo overheating and blackening of the surface which difficult to remove in subsequent operations.

Usually polishing operations start with a 1 grade emery. The abrasive is usually coated soft fabric, such as, sewn sections of drill clo or felt. The abrasive is either glued to the surfa or applied in the form of cake or soap.

Conclusions

We are already receiving enquiries from ma interested parties to assist them in fabricati several items of equipment. In this connectio it may be stated that a set of equipment for maki 'Sago' from Tapioca tubers was fabricated in t Institute and supplied to a firm in Trichur. O intention is to make 'Prototypes' of various fo processing equipment which will form the ba on which other fabricators could start their wo The Planning Commission has sanctioned a spec grant of 5 lakhs during the Second Five Y Plan period for developing the work on 'Fabri tion of Food Processing Equipment'. If work done in the Institute helps in the establi ment of a few centres in India—in the public private sector—for design and fabrication equipment required by the food and fine c mical industries, the work will have been am justified. It is hoped that this will be so.

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